Cranfield University at Silsoe

INSTITUTE OF AGRITECHNOLOGY

September 2001

Postharvest quality of conventionally and organically grown banana fruit

By

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Master of Science by Research in Postharvest Technology

Academic year 2000/2001

Submitted on September 2001

THIS THESIS IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCES

Abstract

Quality is increasingly important for retailers, who tend to look for more definitive assessment criteria. Taste has become a major issue over past years for consumers, who are seeking higher quality produce. For banana fruit, at least one major retailer is asking TSS measurement in addition to the usual assessment based on skin colour. At the same time organic produce sales are increasingly important for ripeners and retailers to consumers.

This study investigated variability in banana pulp with regard to sampling position from proximal, middle and distal portions. Also two different devices, the traditional pocket refractometer and the digital refractometer were evaluated. TSS was measured on juice obtained directly from the pulp, as practised by one supermarket representative, versus the more conventional method of homogenizing pulp samples in distilled water. Finally, a comparison of postharvest qualities of conventionally and organically grown banana fruit from nearby plantations in the Dominican Republic was made. This comparison involved several harvest times over the seasonal period from February to June 2001.

Green mature Cavendish bananas var. Grand Nain were imported from the Dominican Republic by SH Pratt's & Co. (Luton, UK). Both the conventionally and the organically grown bananas from the same area were held at about 15°C during shipping and handling. The fruit were then ripened in a postharvest laboratory in the UK with a shot of 100 µL/L ethylene applied for 48 hours at 20 ±1°C. They were then assessed over 12 days of shelf life at this same temperature and at 60 ±10 % relative humidity. Fruit weight (g), colour (L* and H°), acidity (ml of 0.1 N NaOH), firmness (N) and TSS (%Brix) were assessed every second day during shelf life. In addition, starch breakdown was visualised by dipping slices of banana in iodine solution. Sensory analysis on the ripened fruit was also made with 30 panellists for four out of six of the harvest times.

The results suggest that for measuring sugar as a quality parameter, sampling should be done from the middle of the fruit. Also the conventional diluted extract sampling method is to be preferred. The pocket refractometer (0-30% range) was well suited for making TSS measurements. There were virtually no significant differences ($P \leq 0.05$) in objectively postharvest qualities between conventionally and organically grown fruit. Moreover sensory analysis confirmed this conclusion.

Dedication

To my friend Sophie

Acknowledgements

I would like to thank

- *My supervisor Professor Daryl Joyce for his guidance and advice;*
- *Severine Ruel, Brice Lamarque and all the employees from SH Pratt's &Co, (Luton UK) for their co-operation in this project;*
- *Dr. Anwar Haque and Dr. Helen White for their advice in thesis committees;*
- *Allen Hilton for his grateful help in the laboratory;*
- *Dr John Orchard through his professional collaboration for this thesis;*
- *All the panellists who kindly agreed to take part in sensory analysis;*
- *Paul Dauny and Leon Terry for their help and support all year long;*
- *Xavier Morat, Benoit Lallement, Cecile Gamby, Laetitia Bouchut, Caroline Paolucci and Stephane Gueritte for their precious help;*
- *My family and the Silsoe family for their moral support during this intensive year.*

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List of abbreviations

ANOVA: Analysis of variance
BBC: British Broadcasting Corporation
BGA: Balagon Grower's Association
CA: Control atmosphere
CSIRO: Commonwealth Scientific and Industrial Research Organisation
CO_2: Carbon Dioxide
C_2H_4: Ethylene
cm: centimetres
EU: European Union
EC: European Community
e.g. for example
FAO: Food and Agricultural Organisation of the United Nations
FW: Relative Fresh Weight
g: grams
H°: Hue angle
h: hour
ha: hectare
INIBAP: International Network Improvement of Banana and Plantain
kg: kilograms
$KMNO_4$: Potassium permanganate
L*: lightness
L: litre
LSD: least significant difference
NaOH: Sodium hydroxide
MA: Modified atmosphere
MAFF: Ministry of Agriculture Fisheries and Food
mbar: millibar
min: minutes
mg: milligrams
ml: millilitres
mm: millimetres
m^2: metre square
MRL: Maximum Residue Limits
Mt: Million ton
1-MCP: 1-Methylcyclopropene
N: Newton
n: number of replications
O_2: Oxygen
pH: measure of acidity
Pi: inorganic phosphate
plt: plant
RH: Relative humidity
rpm: revolution per minute
s: seconds
SEM: mean standard error
SPS: Sucrose phosphate synthase
SS: Sucrose synthase
t: tonnes
TA: Titratable Acidity
TSS: Total Soluble Solids
UK: United Kingdom
UV: Ultra violet
US: United States
w/v: weight to volume
µg: micrograms
µL: microlitres
°C: Degrees Celsius
%: Percentage

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1 Introduction

1.1 Background

Banana (*Musa* sp.) is one of the most important fruit grown and consumed world-wide. Banana fruit is grown in more than 100 countries, mainly in sub-tropical areas (Stover and Simmonds, 1987) and the biggest exporters are mainly situated in South America, the Caribbean, West Africa and South East Asia. The biggest markets for banana are North America and Europe, followed by Japan and Eastern Europe (Loeillet, 1999). The Cavendish variety is the most widely consumed dessert banana fruit in Western countries like in the United States. Mr Debus, vice president of the International Banana Association is quoted as saying "bananas are still the number one fruit bought by consumers" (Americafruit, 2001). Banana ranks third place in world fruit volume production after citrus fruit and grapes at 64.6 Mt (FAO, 2000), and second place in trade after citrus fruit, at 14.7 Mt (FAO, 1999a). However producers need to fight for market share where unstable politico-economic situations were predominant until recent market trade agreements between the EU and the US were achieved (Eurofruit, 2001). Growers also face other significant problems such as disease like Black Sigatoka, introduced in the early 1980s (INIBAP, 2000), which recently appeared in one of the last unaffected countries, Australia, (Mintel, 2001). Growers also undergo climate change like in 1998 where the El Nino phenomena and several storms (Georges and Mitch, 1998) damaged plantations in South and Central America and the Caribbean (Loeillet, 1999).

The chain from growers to consumers involves production, harvest, treatment, packing, transport, ripening and retailing. Objectives of banana importers have been to improve shelf life, appearance and eating quality (CSIRO, 1972). Today with organic produce, another retailing opportunity is being taken. A survey conducted by "Health Which?" magazine found that 29% of people opt to eat some organic produce, where fruit and vegetables was the most popular product (BBC News, 2000). Global fresh organic bananas imports in 1998 were estimated at 4% compared with total banana imports (Sauve, 1998). In 2000, total exports reached an estimated 65,000 tonnes 50% more than in 1999 (Eurofruit, 2001). The main market are the EC, the United States, Japan, and Canada (FAO, 1999c). The main supplier to the EC is the Dominican Republic which represents over 80% of the European supply in 1998

(FAO, 1999c). After Germany, the UK is the second largest market which has expanded rapidly due to the strong involvement of the leading supermarket chains (FAO, 1999c).

Quality is an increasingly challenging issue for retailers, especially now with organic produce, who tend to focus on consumers' wishes. The present research investigates variabilities in Total Soluble Solids (TSS) in bananas imported into the UK. Considerable work has been done for banana on preharvest quality improvement and on postharvest physiological and biochemical studies of, for instance, starch into sugar conversions (Lizana, 1976; Marriott *et al*., 1981; Garcia and Lajolo, 1988; Cordenunsi and Lajolo, 1989; Agravante *et al*., 1990; Hill and Rees, 1994; Kanellis *et al*., 1989; Prahba and Bhagyalakshmi, 1998). However there has been surprisingly little work on simple banana quality evaluation tests. Some sectors of the retail industry seek a simple and precise quality criterion other than skin colour.

1.2 Aim

The aim of this work was to relate variation in TSS to pulp sample tissue type and to fruit origin.

1.3 Objectives

The specific objectives of this work were to investigate in collaboration with SH Pratt's & Co (Luton, UK) variability in banana fruit TSS as a function of:

1. Pulp tissue sample position within the fruit,
2. Fruit position within the hand,
3. Ripening over time, and,
4. Organic versus conventional production practices.

1.4 Plan

This thesis is presented in three parts. The first part, the Literature Review, considers banana quality and ripening from physiological and technical perspectives. Then, the experiments are described under the two sections:

1. Within fruit and within hand variation in TSS over time, and,
2. Preharvest production system effects on TSS.

Finally, overall conclusions and recommendations are made in the general Discussion.

2 Literature Review

2.1 Banana physiology, transport and commercial ripening

Before reaching the supermarket shelves, green-mature banana fruit are transported and ripened in the country of consumption (Kashmire and Ahrens, 1992). Retailers require good shelf life and ideally perfect quality. To appreciate the technologies used in postharvest processes, an overview of banana fruit physiology may be helpful.

2.1.1 Physiology

2.1.1.1 The Climacteric

Banana fruit ripening is characterised by many changes. Fruit respiration rate and ethylene production are the main physiological factors that change and define the climacteric group of fruit, which includes banana (Holl, 1977). This grouping also includes apple, avocado and mango (Kader, 1992). Three main events occur after harvest of banana fruit (John and Marchal, 1995): 1. the preclimacteric phase, where the fruit remains unripe; 2. the ripening phase, where respiration rate is high; and, 3. the senescent phase, when quality starts to deteriorate.

The preclimacteric period after harvesting is vitally important for importers and ripeners because banana is transported before it is ripened. During this period, mature-green fruit have a low basal respiration rate and ethylene production is almost undetectable (Marriott and Lancaster, 1983). This period is also called the “green life”. The longest practical preclimacteric period is desired. Green life can be extended by decreasing temperature to 14°C, and storage under low O_2 ($\leq$ 8%) and high CO_2 ($\geq$ 2%) and also by treatment with giberellins (Marriott and Lancaster, 1983).

After their green life, bananas enter the climacteric period, which can be typified by three major sets of processes (Seymour *et al.,* 1993): 1. a sharp rise in respiration, indicated by an increase in carbon dioxide (CO_2) production; 2. a decrease in the internal tissue (i.e. pulp) oxygen (O_2) level; and, 3. a rapid and transient peak in endogenous ethylene production. This climacteric behaviour helps to determine appropriate handling and storage protocols (Mitchell, 1992). The respiratory climacteric can occur on the plant or after harvest. In the case of commercial banana, it is induced by exposure to exogenous ethylene before the natural production commences.

2.1.1.2 Role of ethylene

Ethylene gas (C_2H_4) is a natural plant hormone produced by many horticultural commodities (Reid, 1992). For banana and other climacteric fruit, its role is to co-ordinate ripening (Burg and Burg, 1965). Ethylene is also used commercially for degreening mature citrus fruits (Kader and Kashmire, 1984). In climacteric fruits, ethylene is produced in relatively large amounts. For ripening banana, internal concentrations range between 0.05 and 2.1 μL/L (Wills *et al.*, 1998). Endogenous ethylene production from 0.1 to 4.0 μL/kg/h is often induced by exogenous ethylene (John and Marchal, 1995).

Ethylene is physiologically active at very low concentrations, such as 0.1 μL/L (Peacock, 1972). Ethylene is synthesised in the pulp (Dominguez and Vendrell, 1994) from methionine through the key intermediates S-Adenosyl Methionine (SAM) and 1-aminocyclopropane-1-carboxylic acid (ACC), a cyclic amino acid (Figure 2.1; Yang, 1985). The enzyme involved in the conversion of SAM to ACC is ACC synthase. Conversion of ACC to ethylene is by ACC oxidase, otherwise known as EFE or the Ethylene Forming Enzyme (McGlasson, 1985). In climacteric fruits, increasing ethylene production and increasing respiration are strongly related.

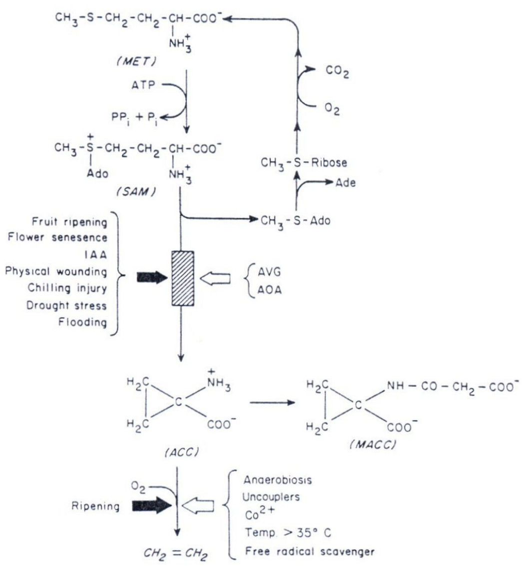


Figure 2.1: Regulation of ethylene biosynthesis This reaction is normally suppressed and is the rate-limiting step in the pathway; ➨, induction of synthesis of the enzyme; $\Leftarrow$, inhibition of the reaction. Met, Ado, Ade and MACC stand for methionine, adenosine, and 1-malonyaminocyclopropane-1-carboxylic acid, respectively, from Yang, (1985).

2.1.1.3 Ethylene and respiration

At first, unripe banana fruits produce ethylene at constant but low rates (e.g. 0.05 µl C_2H_4/kg/h, Figure 2.2). Then, ethylene production rises dramatically and respiration increases (Biale *et al.*, 1953). Peak ethylene production (e.g. 3 µl C_2H_4/kg/h) is reached while respiration is still increasing. At 15°C, the typical respiration rate of green banana fruit is 45 mL CO_2/kg/h, rising to 200 ml/CO_2/h in ripening fruits (Wills *et al.*, 1998). When the climacteric has peaked, ethylene production drops rapidly and respiration reaches its maximum (e.g. 125 ml CO_2/kg/h) (Seymour *et al., 1993*). Ethylene production usually increases with greater maturity at harvest, with physical injuries, increased disease incidence, at increased temperature (Peacock and Blake, 1970) and under water deficit stress (Kader and Kashmire, 1984). To achieve optimum fruit quality, postharvest technologies are managed in order to modulate the physiological processes of ripening banana fruits.

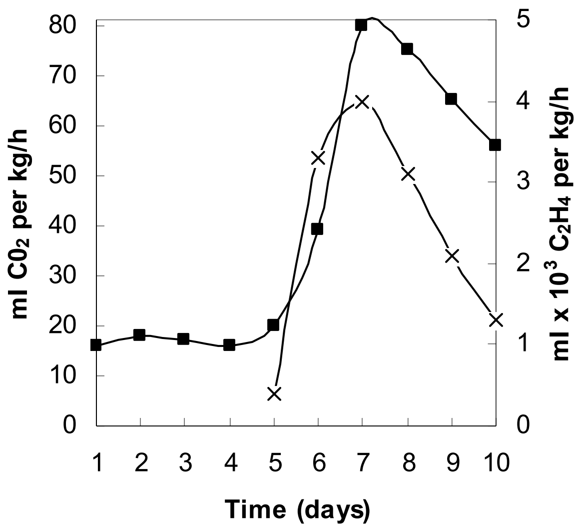


Figure 2.2 Fruit respiration and ethylene production of banana fruit at 20°C, ■ CO_2, and x C_2H_4 production, from Biale *et al.*, (1953).

2.1.2 Transport and storage

Banana, as a tropical fruit, is sensitive to low temperatures (under 12°C) (Wills *et al.*, 1998). Exposure to these temperatures can cause chilling injury (Kader, 1992). Other factors such as high temperature and gas atmosphere composition also markedly influence quality (Mitchell, 1992). The banana is considered a "very perishable fruit" (Wills *et al.*, 1998). From the plantation to the ripening rooms through the packing station and the ships, the aim is to deliver fruit in a firm green condition and as free of blemishes as possible (Stover and Simmonds, 1987). Thus, banana fruit quality is directly affected both by handling and by storage conditions (Shewfelt, 1993). Three main storage methods are used for banana fruit: refrigeration, controlled atmosphere (CA), and modified atmosphere (MA).

2.1.2.1 Refrigeration

In the tropical producer country, the time between cutting and refrigeration should not exceed 24 hours (SICABAM, 1998). After that, there is a risk of damage. Prolonged exposure to temperature above 30°C causes "boiling" or soft pulp with green skin (Rippon and Trochoulias, 1977). The aim is to increase the preclimacteric period by decreasing the temperature. Optimum storage conditions for bananas are about 13-

14°C with a relative humidity of 85-90% (Sommer and Arpaia, 1992). During transport by sea, banana boxes are kept for up to 28 days in normal banana carton (Stover and Simmonds, 1987). Today, however, improved controlled atmosphere or modified atmosphere systems can also be used.

2.1.2.2 Controlled atmosphere (CA)

CA storage is a technique for maintaining the quality of produce in atmospheres that differs from air with respect to the proportion of O_2, and / or CO_2 (Abdullah *et al.*, 1990). Respiration and ethylene production rates of bananas fall in a CA store of 2-5% O_2 and 2-5% CO_2 (Reid, 1992; Kader, 1999). Low O_2 also slows down accumulation of sugars and development of the yellow colour (Kanellis *et al.*, 1989). Postharvest life potential of mature-green bananas at 14°C is 2-4 weeks in air and 4-6 weeks in CA. Madrid and Lopez-lee (1998) reported no difference in colour (L* value and Hue value), firmness and Brix at colour stage 4 between banana fruit stored at 16°C and 95% RH in air or in 3% O_2.

2.1.2.3 Modified atmosphere (MA)

MA storage is similar to CA storage except that atmospheric composition is obtained through the combined effect of respiration and the use of sealed semi-permeable enclosures (e.g. polyethylene bags) (Abdullah *et al.*, 1990). Increase in CO_2 concentration within the container suppresses the activity of many enzymes that normally increase during ripening CO_2 (Abdullah *et al.*, 1990). However, in MA storage, ethylene accumulation in polyethylene bags can cause green ripe banana fruit when the storage period is too long. Removal of ethylene from storage atmosphere can increase the green life of banana fruit (Saltveit, 1999). Thus, potassium permanganate ($KMNO_4$) scrubber can be used in bags as an ethylene absorbent. $KMNO_4$ converts ethylene into CO_2 and H_2O. Reported shelf lives of banana fruit held at 20°C were 7 days in air, 14 days in sealed polyethylene bags and 21 days with sealed bags and $KMNO_4$ (Wills *et al.*, 1998). A Banavac MA system, where bags are evacuated before sealing, has been developed (Badran and Lima, 1969). With this technique, green fruit can be kept up until 40 days (Stover and Simmonds, 1987).

2.1.2.4 Other treatments to extend storage.

Generally irradiation can retard ripening and extend the shelf life of fresh banana fruit (Abdullah *et al*., 1990). In Dwarf Cavendish, ultraviolet (UV) light treatment markedly delayed ripening of mature fruit (Garcia, 1976). Surface coating, or waxing, involves application of a thin film of natural or artificial material to the fruit surface, which reduces transpiration and respiration (Abdullah *et al*., 1990). In Cavendish banana, ripening can also be delayed by a 1.5% prolong dip (Lizada and Novenario, 1983). Srivastata and Dwivedi (2000) reported that 10^{-4} M salicylic acid treatment delayed the ripening of banana fruit. Harris *et al*., (2000) reported the use of 1-Methylcyclopropene (1-MCP) to extend storage of unripe “Williams” bananas was limited due to the variation of 1-MCP effect on fruit maturity.

2.1.3 Commercial Ripening

Optimum conditions are needed to obtain uniform ripening. Ethylene gas is used to initiate and modulate ripening in combination with careful temperature and humidity control (Rippon and Trochoulias, 1977; Kader, 1992). Ripening is often initiated using 1000 μL/L ethylene (1 litre/m^3) for 24 h (Thompson, 1996). Optimal ethylene concentrations have been found for different varieties (e.g. Gros Michel, 0.1 - 1.0 μL/L; Lacatan, 0.5 μL/L and Silk Fig, 0.2-0.25 μL/L) (Reid, 1992). The gas used in ripening rooms is often a mixture of 5% ethylene (20 L/m^3) in nitrogen. Ethylene is also used for the ripening organic banana fruit (Soil Association, 2000).

Careful control of temperature is the most important factor when ripening bananas (Rippon and Trochoulias, 1977). Ethylene is applied when the pulp temperature is around 14-18°C. At < 13°C, banana fruit can suffer chilling, which causes uneven ripening (Stover and Simmonds, 1987). Limiting the rise in the internal pulp temperature is also important. At first, ethylene is administrated for 24 h to fruit with pulp temperatures of 15.5°C - 16.5°C (Stover and Simmonds, 1987). Once begun, ripening can be slowed by lowering the temperature to 13°C or hastened by raising the temperature to 18.5°C (Sommer and Arpaia, 1992). Most retailers ask for fruit at yellow colour or stage colour 4 (Madrid and Lopez-Lee, 1998) (Figure 2.3). Ideally, banana fruit should have a good residual shelf life. Maximum colour is obtained rapidly at 20-24°C whereas, the maximum residual shelf life is obtained by ripening more slowly at 16-17°C (Thompson, 1996). Peacock, (1980) also provided a table showing the time required to reach various CSIRO standard colour index scores in relation to temperatures. Blankenship and Herdeman (1995) recommended a constant high humidity of 95% RH during ripening in order to obtain better quality banana fruit compared to lower RH. Humidity can be increased by steam or spray (Sommer and Arpaia, 1992). Ripening rooms must be well insulated and provided with both heating and refrigeration (Sommer and Arpaia, 1992). Ripening rooms need air circulation and ventilation systems, as good air circulation and exchange is important. The rooms must also be airtight if the “shot system” of ethylene treatment is used. Room design, stacking pattern, and fruit carton design can also affect banana fruit ripening (Marriott and Lancaster, 1983). Many defects can occur when the conditions are not optimal (Table 2.1, CSIRO, 1972)

In addition to storage and ripening condition influences, banana quality depends on numerous physical and chemical changes.

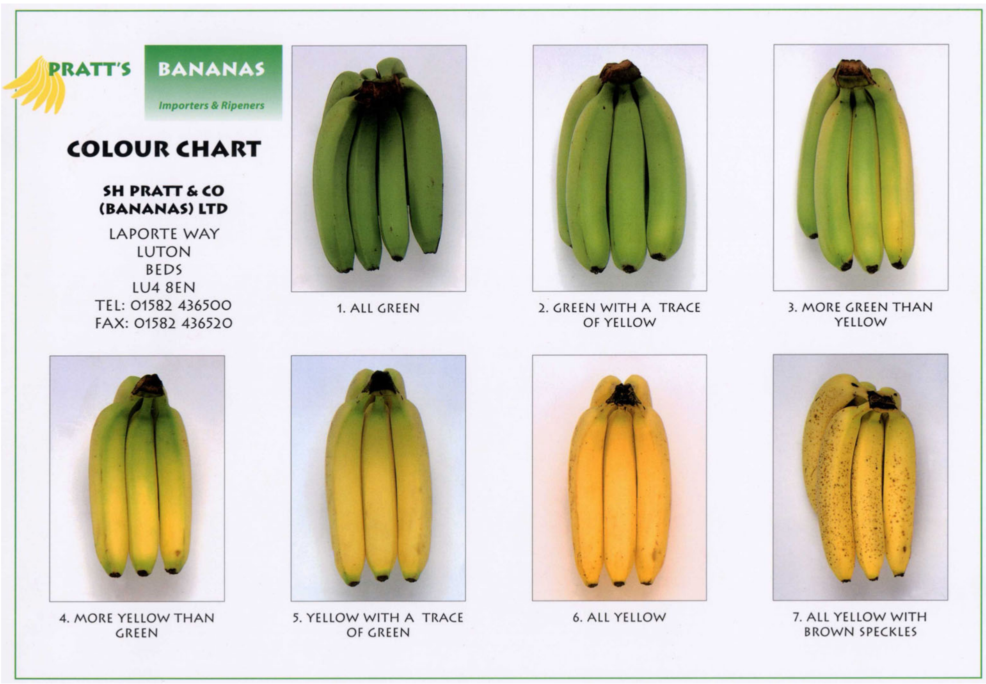


Figure 2.3 Colour chart, SH Pratt’s & co, (Luton, UK).

Table 2.1 Some common faults in ripened Australian Bananas[A]

1. Dull colour is due to:
1.Winter grown fruit subject to low temperature in the plantation or chilled during transport
2 Pulp temperatures allowed to rise above 23 °C
3 Relative humidity too low in the early stages of ripening
4 Fruit removed from the ripening room too early especially in hot or cold weather
5 Poor flavour and rapid deterioration of ripe fruit:
2. Pulp temperature too high during ripening
1. Fruit removed from the ripening rooms too early in hot weather
2. Bananas exposed to too high temperatures in retail shops
3. Humidity too high in the later stages of ripening
4. Fruit received in a heat-affected condition
3. Flecking begins before the fruit is full yellow:
1 Pulp temperature too high during ripening
2 Fruit removed from the rooms too early
3 Fruit received in a heat-affected condition
4. Failure of the pulp to ripen completely although the appearance is good
1 Fruit is inherently "rubbery"
2 Pulp temperatures too low during ripening
3 Fruit removed from the ripening room too early
5. When fully ripe, the peel is soft, easily broken or splits:
1 Humidity is too high in the later stages of ripening
6. Development of black-end and anthracnose:
1 Fruit not treated with a recommended fungicide at packing
7. Fruit shrivelled at the stem, ripening slow, peel showing excessive blackening of even minor injuries, shrinkage excessive
1 Humidity too low

[A]After CSIRO, banana ripening guide, 1972

2.2 Quality of ripening banana

2.2.1 General changes in the ripening banana

Ripening transforms inedible mature fruit into a both visually attractive and edible banana fruit. Changes occur both in the peel and pulp, and edible fruit quality is achieved with enhanced flavour via improved task (e.g. sugar content) and aroma (Table 2.2).

Table 2.2 Changes that occur during banana ripening[A].

General changes	Specific changes
Colour	Breakdown of chlorophyll in the peel (green to yellow).
Texture	Alteration in the composition of cell wall.
	Increase in Tissue permeability (change in water relations of peel and pulp cells).
	Softening of pulp (solubilisation of pectins and hydration of cell walls).
	Hydrolysis of starch and accumulation of sugars.
Metabolic	Increase in respiration and transpiration rate.
	Synthesis and evolution of Ethylene (increases just before ripening).
	Altered regulation of existing metabolic pathways.
	Changes in the fatty acid composition of peel and pulp.
	Increase and activation of enzymes.
	Production of proteins.
Flavour and aroma	Decrease in active tannins in the peel and pulp.
	Production of volatiles.

[A]After Wills *et al.*, 1998.

2.2.1.1 Pigment changes (colour, visual appearance)

The colour of banana fruit changes from green to yellow. This is due to chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments (Marriott and Lancaster, 1983; Stover and Simmonds, 1987; Seymour, 1993). The stage of colouration is an excellent indicator of the probable composition of banana fruit. The colour chart is now used widely for quality evaluation within industry (Figure 2.3).

2.2.1.2 Cell wall changes (firmness and texture)

Banana fruit softening is due to alteration in cell wall structure by degrading enzymes (e.g. polyglacteronase) and also to degradation of starch (Seymour, 1993). Softening occurs rapidly. It is principally the result of the interconversion of pectic substances which represent 0.5 - 0.7% of the ripe pulp (Marriott and Lancaster, 1983, Stover and Simmonds, 1987). Hultin and Levine (1963) and De Swardt and Maxie (1967) showed Pectin Methyl Estserase (PME) activity was involved in the pulp during ripening.

2.2.1.3 Volatile compounds (aroma)

Aroma is a result of volatile production. Banana volatiles include esters, the largest group, alcohols (e.g. aldehydes), carbonyl compounds (e.g. ketones) and phenol esters. Marked volatile synthesis starts late during ripening relative to starch to sugar conversion and to tissue softening. In bananas, the principal aroma volatile compound is isoamylacetate (Shewfelt, 1986). The major banana-like taste is conferred by amyl ester, and the fruity note by butyl ester (Table 2.3) (Seymour, 1993). Optimal flavour is realised when levels of ethanol and its esters are reduced. Over-ripe flavour is observed when these compounds are at high levels. Chilling injury substantially reduces volatile formation. Aroma (flavour) characteristics are usually studied by sensory analysis (Coursey *et al*., 1974; Baldry *et al*., 1981; Ssemwanga and Thompson, 1994).

Table 2.3 Distinctive aroma components of banana fruit[A].

Banana stage	Aroma components
Green	2-Hexenal
Ripe	Eugenol
Overripe	Isopentanol

[A]From Wills *et al*., 1998.

2.2.1.4 Organic acids

At harvest peel and pulp pH is between 5.4 and 6.0. During ripening pH decreases to 4.0 at the fully ripe stage (John and Marchal, 1995). In green Cavendish bananas, citric and malic acids are the most significant organic acids (Table 2.4) (Inaba and Nakamura, 1988). As ripening proceeds, the malic content rises (Satyan and Parwardhan, 1984).

Table 2.4 Organic acid content of bananas[A].

Organic acid (meq/100g fresh wt)	Green	Stage of ripening Yellow/green	Fully Yellow
Malic	1.36	5.37	6.20
Citric	0.68	1.70	2.17
Oxalic	2.33	1.32	1.37
Other acids	0.19	0.16	0.17
Total	4.43	8.74	10.90

[A]From Wyam and Palmer, 1964.

2.2.1.5 Nutrients

Banana has a low fat content and is rich in potassium, magnesium and phosphorous (Table 2.5). It is also a source of iron and calcium and vitamins A (0.1 mg/100g) and C (12 mg/100) (Marriott and Lancaster, 1983). Banana fruit is strongly recommended by nutritionists (Chandler, 1995), and highly appreciated by consumers because of its flavour and sweetness. Compared to other fruits like apples, oranges, pears, and peaches, banana has two or three times the level of carbohydrate; and around 50% more than grapes (The Banana group, 2000). L'Homme *et al*, (2001) found that banana, with plum, contain the highest levels of fructans (about 6000 µg per gram dry matter), which are food non-digestible carbohydrates that exert beneficial nutritional effects.

Table 2.5 Typical composition of unripe and ripe banana fruit (g/100g edible portion of macronutrients and mg/100g of vitamins and minerals)[A].

Composition	Unripe	Ripe
Water	71.9	75.2
Protein	1.9	1.7
Fat	0.1	0.1
Sugar	1.3	17.3
Starch	21.2	3.1
Dietary Fibre	3.2	2.8
Vitamin C	18	12
β Carotene	0.2	0.1
Potassium	320	350
Calcium	5	5

[A]From Wills *et al.*, 1998.

2.2.1.6 Carbohydrate change (starch to sugar hydrolysis)

Carbohydrate changes are important because resulting sugars give sweetness to banana fruit. Carbohydrate content is variable between cultivars (Marriott and Lancaster, 1983). Unripe banana is mainly composed of starch, which represents 20-25% of the fresh weight of pulp and 3% of the fresh weight of peel (Table 2.6) (Seymour., 1993).

Two starch degrading enzymes appear to convert starch to sugar (Table 2.7) (Kader, 1992, Hill and Rees, 1994). Cordenunsi and Lajolo (1995) reported that Sucrose Synthase (SS) activity was almost abolished during ripening and that Sucrose Phosphate Synthase (SPS) activity increased concomitantly to starch disappearance and sugar accumulation. α and β-amylase and glucosidase are also enzymes involved in the degradation of starch (Garcia and Lajolo, 1988, Agravante *et al.*, 1990). ATP is required for these conversions. Only a small amount of sugar (5%) is used for respiration (Biale *et al.*, 1953, Seymour, 1993). When fully ripe, banana fruit contain about 1% starch and 23% sugar (Marriott *et al.*, 1981).

Reducing sugars are initially present in small quantities and become abundant during ripening (Gottreich *et al.*, 1969). Starch is converted into sucrose, glucose, fructose and maltose (Mariott *et al.*, 1981; Table 2.8). Sucrose is the predominant sugar at first and increases before the others (Lizana, 1976; Hill and Rees, 1994). The other sugars are present in only trace concentrations (Chang and Hwang, 1990).

Peel colour is well correlated with the starch sugar ratio (Table 2.9 and 2.10) (Stover and Simmonds, 1987). As they become full yellow, they approach maximum sugar content. The TSS level or Total Soluble Solids is a good measure of the sugar content of fruit. Two quick methods are commonly used for TSS measurements. The first determines the specific gravity of the juice using a hydrometer (e.g. for grapes) and the second measures the refractive index using a refractometer (e.g. for oranges) (MAFF, 2000). Readings are given in % sucrose or degrees Brix (°B). Equipment is generally checked or calibrated with the main soluble sugar, sucrose. TSS is a useful index of maturity and / or stage of ripeness. Thus, TSS is often used as a quality criterion (Tables 2.8 and 2.9). To determine the banana ripeness measurement of reducing sugars content with Summer's regent has been be used (Gottreich *et al.*, 1969).

Table 2.6 Carbohydrate composition of unripe and ripe banana[A].

Stage	Sugars (dry matter basis)	Sugars (fresh weight basis)
Unripe	2-8 %	1 %
Ripe	70-75 %	18-20 %

[A]From Marriott and Lancaster, 1983.

Table 2.7 Pathways of conversion of starch into sugar[A].

glucose-1-phosphate	$\longrightarrow$		uridine diphosphate-D-glucose +
1. fructose 6 phosphate	$\rightarrow$ (sucrose phosphate synthase)	$\rightarrow$	sucrose phosphate
2. sucrose phosphate	$\rightarrow$ (phosphatase)	$\rightarrow$	sucrose + Pi

[A]From Seymour, 1993.

Table 2.8 Sugar content (g/100g fresh weight) of banana fruit[A].

Sugars			
Sucrose	Glucose	Fructose	Total sugars
10	4	4	17

[A]From Wills *et al.*, 1998. A difference arises between the value given for total sugars and the total of individual sugars due to rouding of data given in R.B.H wills (1987) Composition of Australian fresh fruit and vegetables, *Food Technol. Aust.* 39:523-6.

Table 2.9 Peel colour and carbohydrate correlation's from SH Pratt's & Co, (Luton) colour chart.

Stage	Peel colour	Sugar (%)	Starch (%)
1	Green	0.1-2.0	21.5-19.5
2	Green-trace of yellow	2.0-5.0	19.5-16.5
3	More green than yellow	3.5-7.0	18.0-14.5
4	More yellow than green	6.0-12.0	15.0-9.0
5	Green tip	10.0-18.0	10.5-2.5
6	All yellow	16.5-19.5	4.0-1.0
7	Yellow flecked with brown	17.5-19.0	2.5-1.0

Table 2.10 Peel colour and carbohydrate correlation's from the Australian Cavendish colour chart (CSIRO, 1972).

Stage	Peel colour	Sugar (%)	Starch (%)	Observations
1	Green	0.5	20.0	Hard, rigid, no ripening
Sprung	Green	1.0	19.5	Bends slightly, ripening started
2	Green-trace of yellow	2.5	18.0	
3	More green than yellow	4.5	16.0	
4	More yellow than green	7.5	13.0	
5	Yellow-Green tip	13.5	7.0	
6	Full Yellow	18.0	2.5	Peels readily, firm ripe
7	Yellow lightly flecked with brown	19.0	1.5	Fully ripe, aromatic
8	Yellow with increasing brown areas	19.0	1.0	Over-ripe, pulp very soft and darkening, highly aromatic

2.2.2 Definition of banana quality

High quality produce, typical of type, clean, free of disease, free of damage and of good flavour is obviously superior to low quality (Harwood, 1995). One definition of quality is a "product that is grown, graded and packed to meet the customers' requirements" (Smith, 1995). A definition of food quality would be "a composite of those characteristics that differentiate individual units of a product and have significance in determining the degree of acceptability of the unit by the buyer" (Shewfelt, 1992). Consumers tend to focus on appearance (Kader, 1992). Industry looks at other criterion during picking, before shipping, during transport, at the ripeners and finally at the retailers (Table 2.11). Today, with changing customers requirements, such as the new choice of organic produce, producers wishing to win a larger market share must consider quality as the most important factor (Smith, 1995). Management of fresh produce quality has moved from product-orientated trade to market-orientated business (Thompson, 1995).

In climacteric fruit, like banana, quality is intimately related to both physiological and commercial maturity. Physiological maturity is the stage of development when a plant or plant part will continue ontenegy even if detached (Shewfelt, 1992). Commercial maturity often equates to ripeners and is the stage of development when a plant or plant part possesses the prerequisites for utilisation by consumers for a particular purpose (Shewfelt, 1992). When ripe, banana fruit shelf life is no longer than 1 or 2 weeks at 13°C (Wills *et al.*, 1998). Shelf life must be maximised and the best flavour and appearance maintained (Harwood, 1995). Various instrument-based techniques are used to measure maturity and ripeness. Subjective (e.g. colour, taste and flesh texture) and objective (e.g. size, weight) quality tests are used for banana fruit (Reid, 1992). Techniques can be non-destructive or destructive.

Table 2.11 General components of fresh produce quality[A].

Main factor	Components
Appearance	Size: dimensions, weight, volume. Shape and form: diameter, depth ratio. Compactness: uniformity. Colour: uniformity, intensity. Gloss: nature of surface wax. Defects: external, internal, morphological, physical and mechanical physiological, entomological.
Texture	Firmness, hardness, softness, crispness, succulence. Juiciness, mealiness, grittiness, toughness, fibrousness.
Flavour (taste and smell)	Sweetness, sourness, (acidity), astringency, bitterness, aroma (volatile compounds), off flavour, off odours.
Nutritive value	Carbohydrates, protein, lipids, vitamins, minerals.
Safety	Naturally occurring toxicants, contaminants, mycotoxins, microbial contamination

[A]From Kader, 1992.

2.2.3 Assessment of quality

2.2.3.1 In producer country

Banana fruit sold to the UK must always meet EC quality standards (Smith, 1995). Minimum EC requirements are assessed on appearance, condition, size, grading and colour. There are four quality standards for most products; namely extra, class I, class II and class III. For banana, quality standard criteria is fruit defect level tolerated, minimum finger length, minimum and maximum grade, cluster size and arrangements and net box weight (Stover and Simmonds, 1987). All produce packed has to be pest free, clean, intact, sound and suitably packaged especially.

For organically grown banana fruit, certification bodies verify that organic plantations are in conformation with organic growing procedures (FAO, 2001). In the Dominican Republic for example there are several certification organisations like BCS OKO-Garantie (Germany), which does more than 60% of the certification in this country (Lopez, 1999; Eurofruit, 2001). Organic banana fruit also has to satisfy requirements of EU Council Regulations No.2092/91 which gives rules and principles of production, inspection, and materials used (Legge, 1999).

Banana fruits are very susceptible to mechanical injury (Wills *et al.* 1998; Table 2.12). Inadequate or inappropriate packaging can result in skin blemishes. Careful quality evaluation before packing is crucial in order to reject unwanted fruit as damage usually becomes more visible upon ripening. (Stover and Simmonds, 1987;

Harwood, 1995). Data recorded are location of stem in the field, age control ribbon colour, stem weight, number of hands, and grade of the middle finger of the 2nd hand and defects (Stover and Simmonds, 1987). The main defects are scarring, bruising, insect damage, fruit spots, maturity stain, softy mould, fungicide, undesirable residues, animal scratches, overgrade, undergrade, deformed hand, and sunburn. After packing, it is often impossible or not financially viable to rectify grading and handling condition problems (Smith, 1995). Non-destructive quality assessment methods are usually used during packing in the producer country (Shewfelt, 1992).

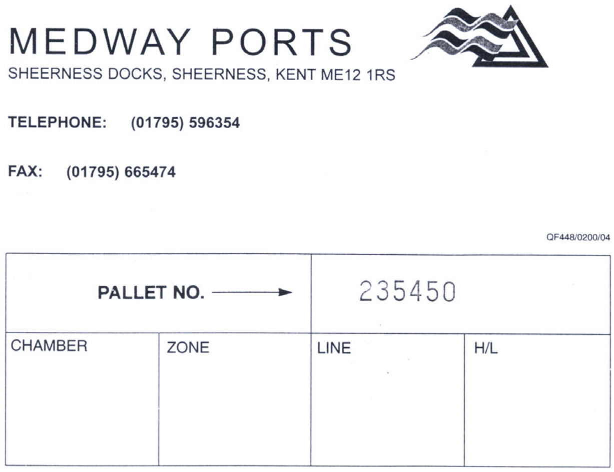
Table 2.12. Susceptibility of banana fruit to types of mechanical injury[A].

Stage	Compression	Impact	Vibration
Green	intermediate	intermediate	susceptible
Ripe	susceptible	susceptible	susceptible

[A]From Wills *et al.*, 1998.

2.2.3.2 At the wharf

Out-turn quality of product is the quality of product reaching the destination market. Produce is usually inspected at the point of off-loading such as the air- or sea-port (Figure 2.4). In the UK, grade, finger length and defects of banana fruit are checked at the discharge port (Stover and Simmonds, 1987). Maturity is the most common out-turn quality problem of banana fruit. Inconsistent maturity between lots and lack of uniform maturity within lots can create market uncertainty in the product, depress price and lead to loss of product (Malins, 1995). Over-mature bananas, which have commenced ripening during shipment and are identified as "ship-ripe" at off-loading, are often rejected at the port of entry. From the Dominican Republic, banana fruit are stored in a connair, a container connected to a cold storage system, before shipping (SICABAM, 1998). Banana fruits often develop the problem of "ship-ripe" because of electricity failures, which stops the refrigeration and CA systems (Lamarque, pers. comm.). Thus, pulp temperatures at off-loading are a useful indicator of potential quality problems (Malins, 1995).


MEDWAY PORTS
SHEERNESS DOCKS, SHEERNESS, KENT ME12 1RS

TELEPHONE: (01795) 596354

FAX: (01795) 665474

QF448/0200/04

PALLET NO. ⟶		235450	
CHAMBER	ZONE	LINE	H/L

Figure 2.4 Pallet label used by the port.

2.2.3.3 At the ripeners

Supermarkets have specific quality requirements they ask to ripeners (Appendix 1). Fruit quality is usually checked immediately upon arrival at the ripeners. In the goods inwards, an expert judge trained for that purpose examines the green fruits (Appendix 2, 2.1). Based on expert judgement, scores are typically given for various quality parameters. The fruit are also checked during ripening (Appendix 2, 2.2), during packing and before being sent to the retailers (Appendix 2, 2.3). Assessment of internal quality attributes is generally by destructive methods and is time consuming (Harwood, 1995). Thus, it is hard for importers to combine both ripening and quality assessments. Commercial pressures restrict the time available for inspection and limit the collecting of quality assessment data (Harwood, 1995). For organic banana fruit, ripeners have to comply with UK soils Association standard St. 10. 101 that states especially that plant and equipment must be dedicated and in separate areas for fresh produce packing (Legge, 1999).

Exceptionally, banana fruit have vertically well–integrated handling and marketing system which allows the producers to be aware of and responsive to market requirements (Malins, 1995). Tracking allows the importer to be aware of the origin of the fruits. For example Savid bananas coming from the Dominican Republic have a number based on “xxx yy zz ss” on each box where xxx represent the container, yy, the area, zz, the plantation and ss, the week it was harvested (Ruel, pers. comm.). Individual fingers can also have a proper label (Figure 2.5).

Figure 2.5. Banana fruit labels from the Dominican Republic (SH Pratt's & Co, Luton). Numbers 57 and 11 show plantation origin and 4011 and 94011 conventionally and organically grown fruit respectively.

Appearance (visual evaluation)

Morphological examination considers size, shape and colour. Size (small, medium, large or extra large) can be evaluated by diameter and length (Banana grading chart, 1986). Banana fruit are often found to be ungraded (Malins, 1995). Colour is one of the most important quality criteria used for banana fruits (Medlicott *et al.*, 1992), especially during ripening. Ripeners have to regulate and check the ripening colour stage twice per day and more frequently nearer the end of the program (Ruel, pers. comm.)

Condition and absence of defects

Mechanical damage before or after harvest becomes visible on the ripened banana fruit. Mechanical damage is the single highest defect category accounting for downgrading of quality in ripened banana fruit (Winban, 1993). Bananas also suffer from postharvest disease such as crown rot, which is caused by a fungal rot complex (Kader, 1999). This rot causes unsightly blackening and softening of the tissues around the cut surface of the crown. Other diseases including anthracnose, stem-end rot and cigar-end rot are also problems for banana ripeners. Latex naturally exudes from the freshly cut surface or stem of banana fruit. Without careful handling, latex can become smeared over the fruit during postharvest handling. Oxidation of latex occurs during shipment, resulting in ugly grey / brown staining on the fruit which adversely affects marketability.

Pesticide residue

Pesticide residue levels, especially for organic bananas, are frequently monitored to check if Maximum Residual Levels (MRLs) are being exceeded (Smith, 1995). At SH

Pratt's and Co (UK), fruit from conventional management plantations MRLs are checked randomly twice a year whereas fruit from all organic plantations are checked (Ruel, pers. comm.).

In the UK the Food Safety Act (1990) states that any party that sells food must show due diligence towards ensuring that it is safe to eat. In the EC, Council Directive 76/895/EEC, sets the maximum residue levels for selected fruits and vegetables and the last revised compilation for banana fruit (128 substances) were compiled under the Commission Directive 2000/24/EC. World-wide, MRLs are set in the Codex Maximum Residue Limits for Pesticides (Codex Alimentarius, Vol 2B). The FAO statistical database (2000) gives 25 MRL pesticides used for bananas in which 5 are used for postharvest treatments.

Texture

For many fruits, texture, firmness or softness is measured by a destructive puncture test or a deformation test (Reid, 1992). For bananas, firmness is not normally measured. However, subjective hand measurements (e.g. sprung bananas) have been devised (Joyce, pers. comm.).

Flavour

Flavour is an issue that has been, until recently, of low importance compared with yield and price (Harwood, 1995). Flavour is now recognised as a vitally important quality attribute. For example, the pursuit of good flavour has led to the genetically modified tomato, Flavr Savr, which also has a longer shelf life when ripe (Harwood, 1995). Flavour can be partly measured by sweetness, which is an important taste element for consumption quality. Sweetness is a function of sugar and acid balance. Sugars are major components of soluble solids. Total Soluble Solids content is measured using a refractometer (MAFF, 1987). The insoluble sugar complex, starch, can be visualised by iodine staining (Chu, 1988). For apples, staining of starch provides a semi-quantitative measure for comparison of maturities using a chart (Reid, 1992). Physicochemical quality tests are only meaningful if they relate to consumer acceptance (Shewfelt, 1992). Sensory evaluations are often used to measure sourness, saltiness, astringency, bitterness and aroma (Kader, 1992). The two major types of sensory tests are preference or acceptance, or semi-analytical tests, which evaluates levels of specific attributes based on the sensitivities of panellists. Samples for sensory assessment have to be prepared and presented at the same time and at the same temperature to tasters with no distraction.

2.3 Preharvest effects on postharvest quality

Quality assessed after harvest is largely the result of conditions and treatments that fruit experience during growth and development and at harvest (Munasque *et al.*, 1990).

2.3.1 Genetic influences

Banana breeding has been existing for *more* than seventy years (Ortiz *et al.,* 1995). Smith (1995) suggested that future developments in the banana fruit sector would depend upon cultivar selection, plant breeding and genetic engineering. The “Musalogue” (INIBAP, 2000) covers most of the diversity in the genus *Musa*, from wild species to cultivated varieties. Varieties differ in many characteristics, including visual appearance (e.g. size), yield and quality. Size, for example small, medium or large, is a matter of consumer preference (Hofman and Smith, 1993). Variety also has an effect on yield, firmness, fibrousness, succulence and juiciness (Kader, 1992). For certain tree crops, rootstock selection may cause differences in fruit TSS and acidity via influences on nutrient and water uptake and translocation or differences in photosynthate partitioning (Beverly *et al.*, 1992). Increasing the energy supply and decreasing the water content of fruit increases TSS in tomatoes (Shewfelt, 1992). Thus, TSS exemplifies a trade off between yield and quality, since yield generally decreases with increasing TSS (Stevens and Rudich, 1978). The genotypic characteristics of any one cultivar vary in response to environmental effects.

2.3.2 Phenotypic differences

Environmental conditions have many effects on the rate of plant growth and development (Shewfelt, 1992). Management factors, like irrigation, fertilisation or pesticide applications also influence quality and shelf life (Kader, 1992).

2.3.2.1 General management

Canopy management

Canopy management focuses on the amounts of light and CO_2 that fruits receive. For banana fruit, full shade gives a dull yellow peel colour whereas partial shade leads to a bright yellow peel colour (Munasque *et al.*, 1990). Low light intensity retards development of carotenoids (Pantastico *et al.*, 1990). An important determinant of banana fruit quality is row spacing and the associated plant population (Stover and Simmonds, 1987). Plant density consists of selecting the most vigorous suckers located in the best places and eliminating undesirable ones (Stover and Simmonds, 1987). This method can increase the number of leaves and fruits exposed to sunlight (Beverly *et al.*, 1992). Removal of leaves can also help prevent fruit scaring. Bunch thinning reduces inter-fruit competition and improves fruit size (Munasque *et al.*, 1990; Beverly *et al.*, 1992). However, an increase in size may decrease firmness and increase physiological disorders (Hofman and Smith, 1993). An average banana plant population is around 2, 500 per ha (Stover and Simmonds, 1987). Plant health and leaf/fruit ratio also influences flavour (Hofman and Smith, 1993). Climatic factors like temperature and relative humidity considerably affect banana fruit. In particular the seasons of summer (from March to September) and winter (from October to February) in tropical areas influence banana fruit characteristics. Winter bananas tend to ripen slower because of low temperature and higher soluble tannin content in the bananas (Chang *et al.*, 1990). High temperatures hasten growth and reproductive maturity and increase respiration, which can decrease the energy stored by plant tissue (Shewfelt, 1992). While climatic variables cannot be changed, light availability and water management can be adapted to suit.

Water management

Field water management is mainly achieved by irrigation. Irrigation requirements like watering and associated drainage are important to fruit growth. Water supply regulates transpiration by the leaves and input through the roots. Depending on the climate and the type of fruit grown, the influences of water supply to fruit can differ. Drought stress can limit crop yield but may either decrease or increase product quality. For tomatoes, water stress increases TSS, acidity and flavour (Mizrahi and Hobson, 1988; Shewfelt, 1992). However, if drought stress increases concentration of most constituents it always reduces yield (Stevens, 1985). For bananas, absence of irrigation induces physiological disorders after harvest; like the green ripe disorder (Munasque *et al.,* 1990). A dry atmosphere induces stomata closure on leaves, which can limit supply of water and nutrients to fruit (Beverly *et al.*, 1992). In this case, humidity should be increased. However, excess water also has detrimental quality consequences for plant. The photosynthetic rate decreases with overly high water availability and low transpiration rates. High moisture content in fruit also tends to dilute the soluble solids leading to low flavour intensity (Beverly *et al.*, 1992). Furthermore, a high relative humidity during fruit development shortens the storage life and increases the incidence of finger drop and crown rotting (Munasque *et al.*, 1990).

<u>Nutrient management</u>

The soil type determines the nature of management. Roots will grow differently in clay or sand. In dry or saline soil, excess solar energy will result in a decrease of water supply. Under these conditions, nutrient supply can be insufficient and fertilisers are required. Nitrogen, which moves from older leaf tissue to new leaf and fruit, usually increases yield but decreases tissue carbohydrates (Shewfelt, 1992; Beverly *et al.*, 1992). High potassium and calcium will give high dry matter and glucose content in the peel and the pulp (Gelido, 1986). Calcium, which may be sprayed via irrigation (Shewfelt, 1992) can reduce physiological disorders and diseases and also delay softening in fruit during ripening (Hofman and Smith, 1993). High levels of potassium results in high organic matter content in Robusta banana (Munasque *et al.*, 1990). Low levels of nitrogen, phosphorus and magnesium give high dry matter in the pulp (Munasque *et al.*, 1990). High level of phosphorus in ripe fruits gives low level of TSS (Munasque *et al.*, 1990). High potassium is often associated with reduced acidity but increased soluble solids in fruit (Hofman and Smith, 1993). High levels of magnesium in the peel induces finger drop in bananas (Munasque *et al.*, 1990).

<u>Pest management</u>

Fruit protection is needed in order to obtain healthy fruits. Deleafing consists of removing old leaves that touch the fruit, debudding stops insect transmission of the Moko pathogen and bagging prevents peel blemishes and creates a green house effect around the fruit to improve growth conditions in the same time (Stover and

Simmonds, 1987). Fruit bagging prevents pest and disease attack during banana fruit growth. Bagging is typically applied to an 8-12 hands bunch. The whole bunch is surrounded with a polyethylene bag typically perforated and impregnated with pesticide. In the case of intense illumination, bags are blue to prevent scalding.

Insects like banana weevil makes holes in the base of the banana plant and banana eelworm or nematode eats the roots. Other pests such as thrips, aphids and scale insects may also damage the fruit (Gowen, 1995). Fungi such as the pathogen that causes Panama disease make the leaves break or for the Leaf spot disease inhibit respiration and the yield falls greatly (Jeger *et al.,* 1995). The bunchy top, disease carried by an aphid prevents the leaves from growing (Jeger *et al.,* 1995). Cigar-end rot rottens banana fruit at the tip. The mosaic disease makes small yellow patches on the leaves (Winban, 1993). Yellow and black sigatoka diseases decrease yield. Application of pesticide and fungicide is made (Shamsudin and Suphrangkasen, 1990). Yellow and black sigatoka is controlled by doing good field sanitary practices (removal of infected material, good drainage) (Orchard and Krauss, 1999). Weeds and nematodes are controlled with manual herbicides and synthetic nemacides respectively (Orchard and Krauss, 1999).

2.3.2.2 Organic management

<u>Nutrient management</u>

Synthetic fertilisers are replaced by composted manures from animal and / or household sources (80/t/ha/yr), mined, mineral fertilisers and green manures (Orchard and Krauss, 1999). In the Philippines organic fertiliser is employed at the rate of 5 kg per plant with 1 kg applied prior to land preparation (BGA, 1998).

<u>Pest management</u>

Organic pest management is based on pest prevention rather than control through an understanding of pest biology and ecology through production of a healthy crop in a balanced and sustainable ecosystem (Holderness *et al*., 1999). Synthetic products are prohibited while other products are allowed only where absolutely necessary and are restricted by certification (Holderness *et al*., 1999). Organic pest management systems include quarantine and pest exclusion, preventative cultural techniques and crop sanitation. The use of resistant varieties, promotion of crop vigour and fertile soils of high biological activity and, where appropriate, use of introduced or augmented biological control agents are also practices (Holderness *et al*., 1999). In the Philippines, spraying of plant extracts such as madrede cacao (*Gliricidia sepium*), neem (*Azardirachta indica*), manungal (*Tinospora rumphil*), tobacco (*Nicotiana tabacum*), chilli (C*apercicum anum*) and lemon grass, is directed to the affected part of the plant (BGA, 1998). For yellow and black sigatoka disease, conventional sanitary practice is replaced by other practices such as early harvesting, and copper formulations and elemental sulphur (US), and mineral oils in (EU, expires on 31/02/2002) applications. For the same disease, fungicides are replaced by biological control (bacteria) and disease resistance varieties (FHIA, IITA) (Orchard and Krauss, 1999).

2.3.2.3 Harvest

Harvest management needs to be well prepared. Attention to maturity stage at harvest is crucial as it profoundly affects ripe fruit quality (Shewfelt, 1992). In order to sell fruit during favourable periods where demand and prices are high, crop trimming, which consists of cutting down mature plants and removing unwanted plants, is done (Stover and Simmonds, 1987). Estimation of the duration of development from anthesis to harvest is commonly used to determine when to harvest banana fruits (Shewfelt, 1992). Bunch age grade control using colour ribbons or coloured bags shows when to harvest bunches and thus to avoid bananas from being too ripe for transport marketing (Thompson and Burden, 1995). Tagging enables growers to relate age of fruit with physicochemical properties during fruit development (Sommer and Arpaia, 1992; Wijeratnam *et al.* 1992). In the end, good yields result from thoughtful production management efforts. Average production around is 2,000 boxes for a small-scale farm and 3,000 boxes for bigger ones, each box containing 18 kg. Yields are typically 37 to 55 tonnes per hectare (Stover and Simmonds, 1987).

2.4 Conclusion

The Mintel (2000) report on fresh fruit and vegetables underlines the fact that health issues remain an important factor in the promotion of fresh fruit and vegetables. The report also asserts that suppliers are aware of the need to compete for markets on attributes such as taste, versatility and convenience. Labelling of product sold in supermarket can carry measures concerning quality to consumers (SH Pratt's and Co, Figure 2.6). For consumers, organic produce, such as organic bananas, notionally represent a healthier way of eating. For supermarket buyers quantitative measures of banana quality, such as TSS measurements are sought to compliment qualitative assessment on the basis of skin colour. Thus, the following study investigating methods of measuring TSS and comparing conventionally and organically grown banana fruit produce was initiated.

Figure 2.6 Label of organically grown banana fruit sold in supermarket (source: SH Pratt's & Co.)

3 Experimental Part 1: Preliminary experimentation concerning TSS measurements

3.1 Sampling position and ripening effects on TSS levels in banana fruit

3.1.1 Introduction

Sweetness is one of the key flavour qualities and can be measured by the amount of Total Soluble Solids (TSS) in those fruit whose major carbohydrate pool is sugars (Kader 1992). Banana fruit peel colour is well correlated with the starch-sugar ratio (Stover and Simmonds 1987) and serves as one of the major criteria used by consumers, growers, and researchers to determine whether a fruit is ripe or unripe (Medlicott *et al*., 1992). Starch and sugar levels in banana fruit during ripening has been the subject of many studies (Marriot *et al*., 1981; Almazan, 1991; Hill and Rees, 1994; Cordenunsi and Lajolo, 1995). Moreover, many investigations looking at enzymes of starch breakdown and sugar synthesis under various conditions have been conducted (Lizana, 1976; Beaudry, *et al*., 1987; Garcia and Lajolo, 1988; Kanellis *et al*., 1989; Agravante *et al*., 1990; Hubbard *et al*., 1990; Chang and Hwang, 1990; Nascimento *et al*., 1997; Madrid and Lopez-Lee, 1998). However, change in banana fruit sweetness as a practical aspect of quality management has not been widely examined.

3.1.2 Aim

The aim of this experiment was to investigate variability in TSS as a function of tissue sampling position from within the fruit. The experiment evaluated starch degradation in the fruit, the increase in TSS and changes in Titratable Acidity (TA) content over time and in relation to peel colour.

3.1.3 Hypothesis

The hypothesis tested was that starch would be converted into sugar at different rates along the banana fruit. Previous researchers have made two relevant observations. Loesecke (1949) and Mao and Kinsella (1981) reported that ripening starts at the ends of banana fruit. Garcia and Lajolo (1988) observed that starch hydrolysis starts at the central core of the fruit and advances towards the periphery of the pulp as ripening proceeds. TSS changes were studied during ripening over time using two different sample extraction methods and two different refractometers for the same samples from the same banana fruits.

3.1.4 Objectives

The specific objectives were:

1. To relate hydrolysis of starch into sugar (TSS) to ripening and colour changes.
2. To determine where starch was converted into sugar both across (by starch-iodine staining) and along (by TSS) the banana fruit.
3. To see how TA changed with ripening and colouration of the banana fruit.
4. To evaluate two methods for testing TA and two methods and two devices for testing TSS.

3.1.5 Materials and Methods

3.1.5.1 Fruit

Conventionally and organically grown green (colour stage 1, according to SH Pratt's & Co's colour chart) Cavendish banana fruit (var Grand Nain) from Costa Rica and Dominican Republic, respectively, were supplied by SH Pratt's & Co. Ltd. (Luton, UK). One box containing 150 banana fruit was collected for each type. At the postharvest laboratory, fruit were initially stored at 15°C for 2 days while the experiment was prepared. Individual fingers were cut from the hands and left for 2 h on paper to let the latex dry. They were then labelled and arranged randomly in apple fruit trays (Figure 3.1). It should be stressed at this point, that while this experiment utilised both conventionally and organically grown bananas, it is not intended as a comparison of these two different production systems.

3.1.5.2 Ethylene treatment

Day 0 was designated the day when ripening was commenced. On day 0 and on day 2 fruit placed at 20°C into an 340 L capacity airtight box received an ethylene shot dose of 100 μL/L. Ethylene levels were quantified using a Carlo Erba (UK) 8000 gas chromatograph with a 2.0 m long x 6.35 mm internal diameter stainless steel column packed with 60-80 mesh Porapack. The oven temperature was set to 150°C. The carrier gas was helium at 40 ml min^{-1}. The chromatograph was fitted with a flame ionisation detector set to 150°C and linked to a Carlo-Erba DP800 integrator. C_2H_4 was calibrated against 0.01 μL/L C_2H_4. After day 2 fruit were moved to ambient air storage at 20°C ±1°C and 60 ±10% relative humidity.

Figure 3.1 Green banana fruit arranged in an open apple tray.

3.1.5.3 Fruit quality attributes

Length, diameter, colour, weight, TSS, TA and starch staining measurements were made (n = 5 individual fruit replications). Diameter (mm) and length (inches converted to cm) of fruits were measured at colour stage 1 only (all green), on day -1 using a digital calliper (Mitutoyo 0-150 mm / 0-6 inches, Japan) (Figure 3.2) and a flexible ruler (Geest, UK), (Figure 3.2).

The later 5 parameters were determined every second day for 12 days. TA, and starch staining were assessed at three points: at 25% of the distance from the proximal end, in the middle, and at 25% from the distal end.

Colour stage was judged visually using a chart scale provided by SH Pratt's & Co (Figure 2.3). Colour of each fruit, was also measured as lightness (L*) and hue angle (H°), (Medlicott *et al.,* 1992) with a Minolta CR-200 colorimeter (Japan) using an 8 mm beam aperture. The instrument was calibrated with a Minolta standard white tile CR-200 (Y=93.9, x=0.3134, y=0.3207). Local differences in surface pigmentation were compensated for by determining the mean of three readings around the surface of the fruit (Medlicott *et al*., 1992).

Weight was first measured on day-1 at colour stage 1 (all green) and then repeatedly on each assessment day. Weight loss was calculated as follows: Relative fresh weight (FW%) = W_1 x 100 / W_o; where W_o was the original weight measured on day 0 and W_1 the weight measured on the assessment day.

TA was measured against a solution of 0.1 N sodium hydroxide (1g / 250ml), with the addition of three drops of phenolphthalein until a pinkish colour change remained.

Starch staining was measured by dipping a cross-section of banana for 2 sec. in an iodine preparation of 4.0% potassium iodide (KI), and 1.0 % iodine (I_2) (Chu, 1988). The pattern of the whole slice and starch stained area was traced onto a transparent plastic sheet (OHT slide), photocopied, and the resultant paper images cut and weighed. Starch staining was expressed as follows: Starch %= W_{st} / W_{sl} x 100; where W_{st} was the weight of starch staining area cut out and W_{sl} the total weight of paper cut out for each slice. On day 2, starch staining was visually estimated due to the little amount of unstained areas.

TSS was measured with a pocket refractometer (Bellingham and Stanley, UK) and a digital refractometer (Atago PR-1, Japan), both scaled from 0-30 % (MAFF, 1987). Undiluted TSS was measured by administrating an amount of banana pulp squashed with a wooden stick directly to the refractometers (Figure 3.3). This crude method is practised by a technical representative of one of the supermarkets, and was therefore of direct interest to the banana ripener, SH Pratt's & Co. Diluted (5-fold) TSS was measured by homogenising banana pulp (at least 2g) in distilled water (Table 3.1) with an Ultra-Turrax T25 (Janke and Kunkel, Germany) for 15 s at 8,000 rpm followed by 15 s at 15,000 rpm (Figure 3.4). Tubes were left for 10 min to settle and TSS of the solution measured (Figure 3.5).

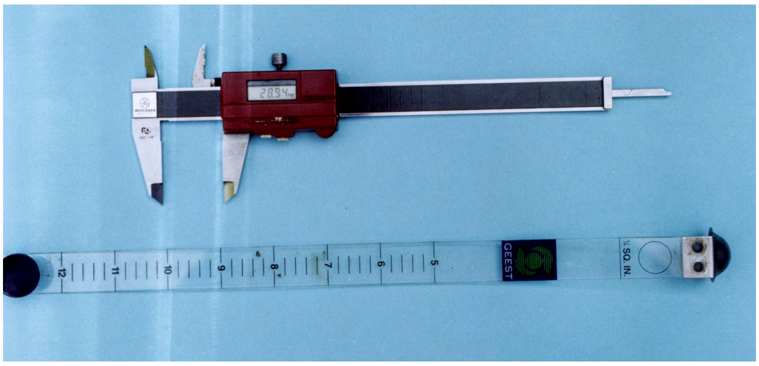


Figure 3.2 Digital calliper (Mitutoyo, Japan) and flexible ruler (Geest, UK).

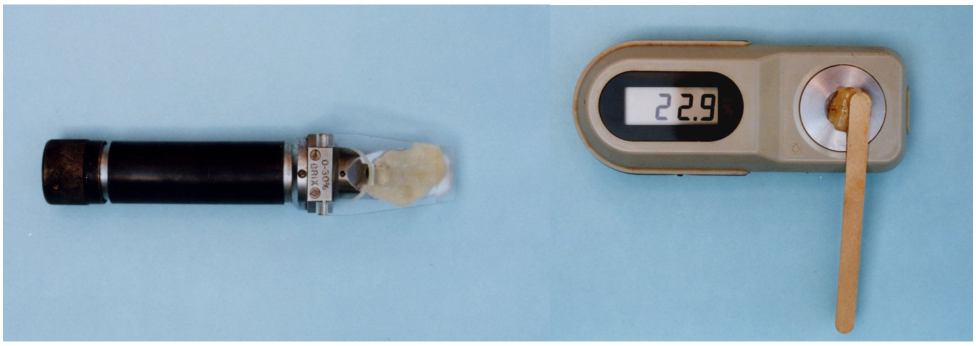


Figure 3.3 Pocket 0-30 % (Bellingham and Stanley, UK) and digital 0-30% refractometers (Atago PR-1, Japan), for the undiluted method.

Table 3.1 Pulp to water diluted scale for TSS measurement by the dilution method.

Pulp (g)	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
Water (ml)	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0

Figure 3.4 Apparatus for homogenisation of banana pulp tissue slices.

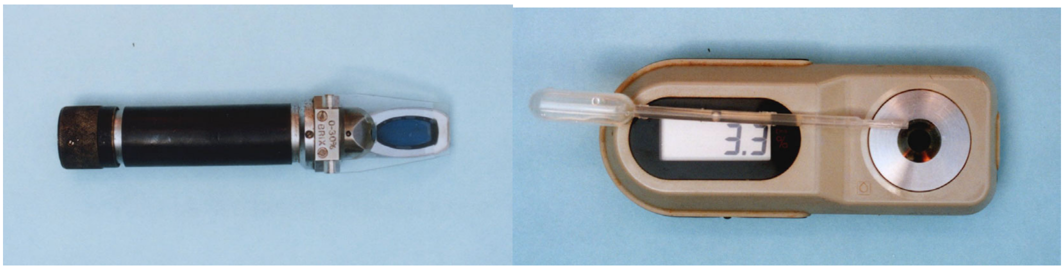


Figure 3.5 Pocket 0-30 % (Bellingham and Stanley, UK) and digital 0-30% refractometers (Atago PR-1, Japan), for the diluted method.

3.1.5.4 Statistical analysis

A Completely Randomised (CR) experimental design was adopted. Data was analysed by Analysis Of Variance (ANOVA) using Genstat 5 Version 4.1 (Lawes Agricultural Trust, Rothamstead, 1996). Testing for differences between means was at the 5% level ($P \leq 0.05$). For significant differences, relative fresh weight and starch staining percentage data were transformed prior ANOVA using the square root and angular transformation, respectively (Steel and Torrie, 1960; Snedecor and Cochran, 1967).

3.1.6 Results

There were significant differences ($P \leq 0.05$) in both length and diameter between the two groups of bananas obtained from conventional versus organic plantations (Table 3.2). Skin colour stage (Table 3.3) reached stage 3 on day 2, stage 6 on day 4, stage 7 on day 6 and finally maintained stage 7 after day 8 until day 12. There were no significant differences between conventionally and organically grown banana fruit from different countries for L* values (Figure 3.6A) and only slight significant differences ($P \leq 0.05$) on day 2 and on days 6 and 12 for H° (Figure 3.6B) and FW (Figure 3.6C), respectively. L* increased between day 0 and 4, reached the maximum on day 4 and then decreased until day 12. H° decreased rapidly from day 0 until day 4 and then at a slower rate until day 12. FW decreased consistently and slowly between day 0 and day 12.

There were no significant differences ($P \leq 0.05$) between banana fruit from the two different origins for TA (Figure 3.7A) and a significant difference ($P \leq 0.05$) on day 6 for starch staining (Figure 3.7C). There were slight significant differences ($P \leq 0.05$) between proximal, middle and distal position on days 10 and 12 and on days 2, 4, 6, 8 and 10 for TA (Figure 3.7C) and starch staining (Figure 3.7D) respectively. TA increased between day 0 and 4 and then decreased after day 4. Starch staining decreased rapidly after day 4 to day 12. The proximal sampling position had slightly lower significant ($P \leq 0.05$) TA content and starch staining than the middle position. The middle, inturn, had marginally lower TA content and starch staining than the distal position.

There were no significant differences ($P \leq 0.05$) for TSS between conventionally and organically grown banana fruit (Figure 3.8A). There were significant differences ($P \leq 0.05$) on days 0, 2, 4, 6, and 8, on days 4 and 6, and on days 0, 2, 4, 6, 8 and 10, for TSS measurement between proximal, middle and distal position (Figure 3.8B), between the undiluted and the diluted method (Figure 3.8C) and between pocket and digital refractometer (Figure 3.8D), respectively. TSS increased markedly between days 0 and 4 and then stabilised until day 12. The proximal and distal position had a slightly significant ($P \leq 0.05$) higher TSS measurement than the middle position. The undiluted method for measuring TSS gave a significantly ($P \leq 0.05$) higher TSS than the diluted method, especially on the first days where the banana fruit were still green. The digital refractometer gave significantly ($P \leq 0.05$) lower TSS measurement than the pocket refractometer.

Table 3.2 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\overline{x}$ ± SE, n = 60.

	Conventional	Organic
Length (cm)	22.62 (± 0.28)	19.22 (± 0.30)
Diameter (mm)	34.44 (± 0.53)	32.04 (± 0.35)

Table 3.3 Colour stage of banana fruits (colour chart, SH Pratt's & Co).

Days	Stage	Colour
0	1	All green
2	3	More green than yellow
4	6	All yellow
6	7	Yellow with spots
8	7	Yellow with increased spots
10	7	Yellow with increased spots
12	7	Yellow with increased spots

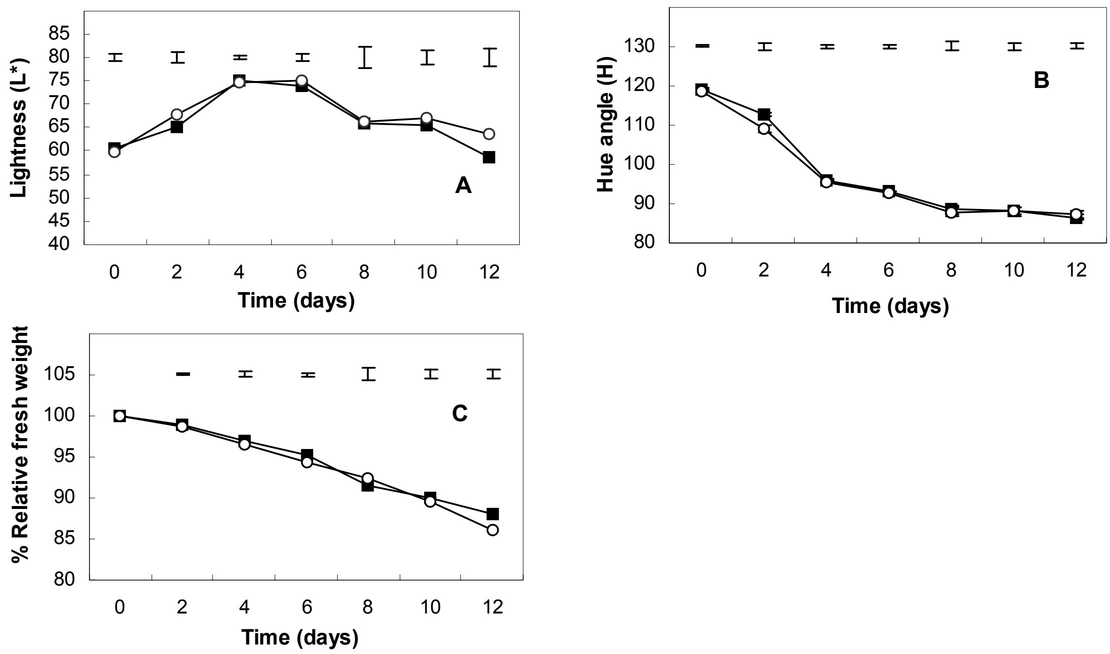


Figure 3.6 Changes in A. lightness (L*), B. hue angle (H°), and C. FW (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruits; data are $\overline{x}$, n = 5, vertical bars show ± SEM, n = 10 (for ANOVA see Appendix 3).

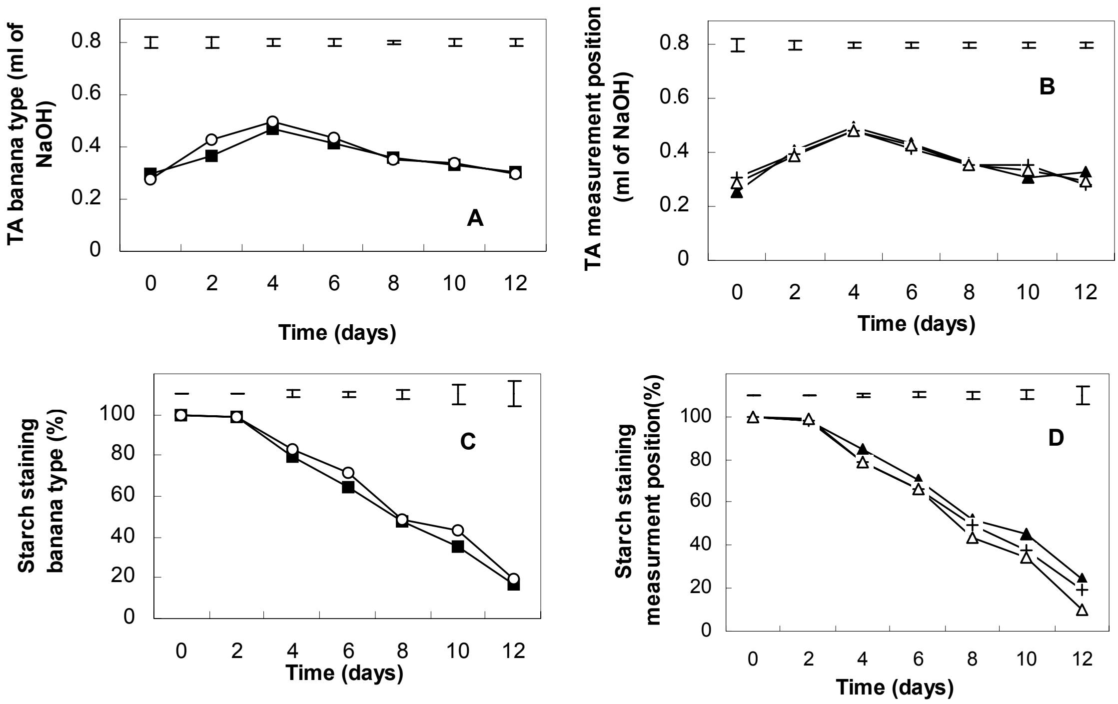


Figure 3.7. Changes in A. and B. TA (ml of NaOH), and C. and D. starch staining (%), measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruits, proximal ▲, middle + and distal △ positionl; data are $\overline{x}$, n = 5, vertical bars show ± SEM, n = 10 (for ANOVA see Appendix.3). In panel A, TA for conventionally grown fruit was not measured on day 0 because of broken apparatus.

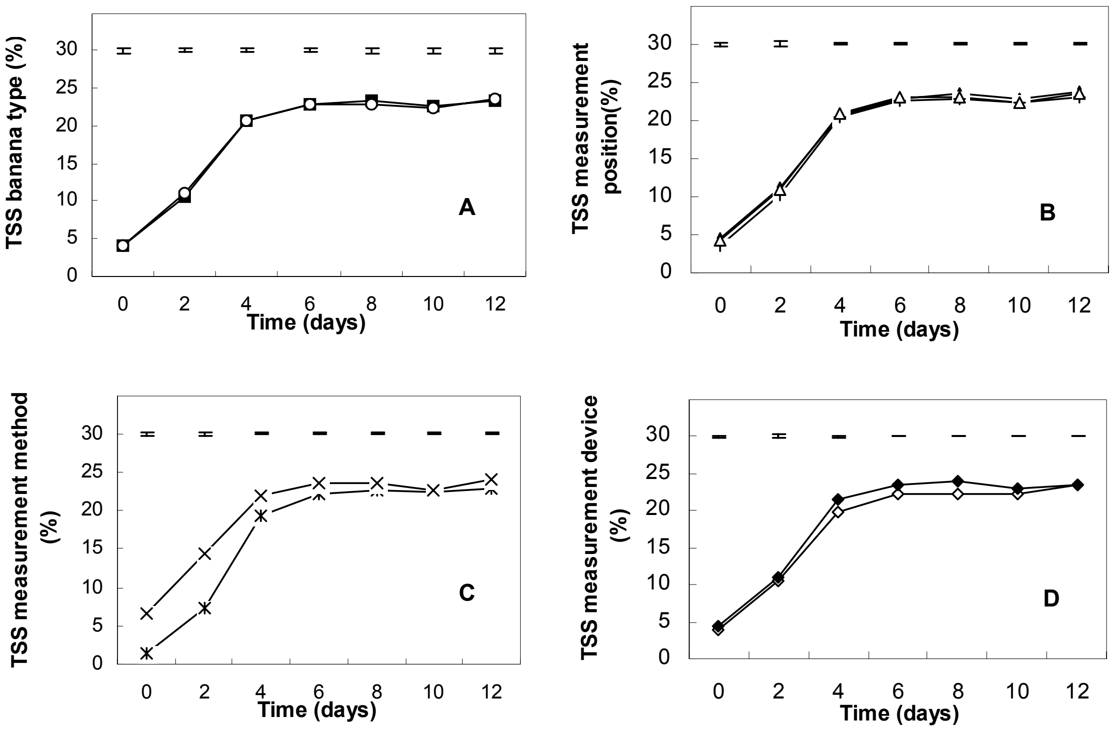


Figure 3.8 Changes in A. B. C. and D. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruits; proximal ▲, middle + and distal △ position, undiluted x, and diluted ⋇ method, pocket ♦, and digital ◊ refractometer; data are $\bar{x}$, n = 5, vertical bars show ± SEM, n = 10 (for ANOVA see Appendix 3).

3.1.7 Discussion

Banana fruit from the conventionally managed plantation in Costa Rica were bigger in size and diameter than organically grown banana fruit from the Dominican Republic. The original size classification for the conventionally grown banana fruit was class I, whereas the organically grown banana fruit were class II (SH Pratt's & Co). Organic bananas are not available in class I (Ruel, pers. Comm.) Low L* values characterise the dark green colour of unripe banana fruits (Mustaffa *et al.*, 1998). Banana fruits became lighter as they ripened to colour stage 6 (all yellow) and then darker again as the fruit developed with brown (senescent) spots (Agravante *et al.*, 1990). The H° decrease corresponded to ripening from colour stage 1 (all green) to colour stage 6 (all yellow) as chlorophyll was degraded and carotenoids became visible (Marriott and Lancaster, 1983; Stover and Simmonds, 1987; Seymour, 1993). H° remained relatively constant thereafter as the banana fruit became overripe and developed brown spots. Banana fruits lost weight due to respiration and transpiration. Weight loss affects appearance, and textural and nutritional qualities (Stover and Simmonds, 1987). TA increased as the banana fruit ripened and then decreased, as the fruit became overripe. Loesoecke (1950) reported a sharp increase in acidity in course of banana fruit ripening.

At the colour stage 1 (all green) starch was not yet converted to sugar. Hydrolysis of starch to sugar appeared to have started slightly on day 2 at colour stage 2 (green with yellow tip) and in the centre part of the banana fruit. Hydrolysis had occurred markedly on day 4 at colour stage 4 (all yellow), as ripening took place. This result was in accordance with Garcia and Lajolo (1988), who found that during the early preclimacteric phase starch was well distributed in the tissue. During the climacteric, commencement of starch degradation to sugar started in the central part of the fruit. Finally as ripening advanced, starch staining such that during the postclimacteric the process was completed and little starch was detected. However, the observation that starch staining slightly differed between position in the present experiment was contrary to results found by Garcia and Lajolo (1988). They stated that the same pattern of starch hydrolysis was seen in the middle section of the fruit and at 2 cm from both ends.

Increasing TSS reflects hydrolysis of starch into sugars as banana fruit ripen. This conversion was reported to be the most important change in ripening bananas (Stover and Simmonds, 1987). Afterwards, total sugar content does not change significantly during the later stage of ripening (Marriott *et al.*, 1981). There was no marked difference in TSS between conventionally grown and organically grown banana fruits. Even otherwise, no difference between conventionally and organically grown banana fruit was to be inferred. The ends of the fruit had slightly higher TSS content than the centre. This result suggested that conversion of starch into sugar was proportionally greater near the ends.

The digital refractometer usually under-scored the pocket refractometer TSS values, especially at the beginning when the banana fruits started to ripen. The undiluted method seemed inappropriate because TSS measurements are not accurate.

3.1.7.1 Conclusions

Standardisation on sampling from the centre was suggested. For experiment 2, to which was added firmness and sensory analysis the undiluted and diluted methods were subjected to further comparisons and only the pocket refractometer 0-30% was used. Accordingly, instruments were subjected to comparative evaluation.

3.2 Checking of refractometers with AR-grade sucrose

3.2.1 Introduction

Before further assessing TSS for bananas a more direct comparison of the refractometers was deemed necessary (see above). Ideally, for pure solutions of sucrose at different concentrations, results given by the different devices (i.e. the pocket refractometer scaled at both 0-30%, and 0-50%, and the digital refractometer scaled at 0-30%) should be the same.

3.2.2 Materials and Methods

Stock solutions of pure sucrose (AnalAR, BDH Laboratory Suppliers) diluted in water were prepared by dissolving 3.2 g in 10 ml or 16.0 g in 50 ml. Five ml was added to the 32% (w/v) solution to give a 16% (w/v) solution. Concentrations of 32, 16, 8, 4, 2, and 1% were prepared. TSS % was then measured with the pocket refractometer scaled 0-50%, the same pocket refractometer scaled 0-30% and the digital refractometer scaled 0-30%. Refractometers were calibrated at 0.00 with distilled water.

3.2.3 Results and Discussion

Overall, the measured data underestimated % TSS (Figure 3.9). This difference could have been due to problems in the solution preparation. The pocket refractometer scaled 0-50% markedly under-estimated TSS at concentration 16 %. The pocket refractometer scaled 0-50% was not precise enough compared to the pocket refractometer 0-30%. The pocket refractometer scaled 0-30% gave good TSS measurements, as did the digital one. The digital refractometer gave slightly lower % TSS values than the pocket 0-30 % refractometer.

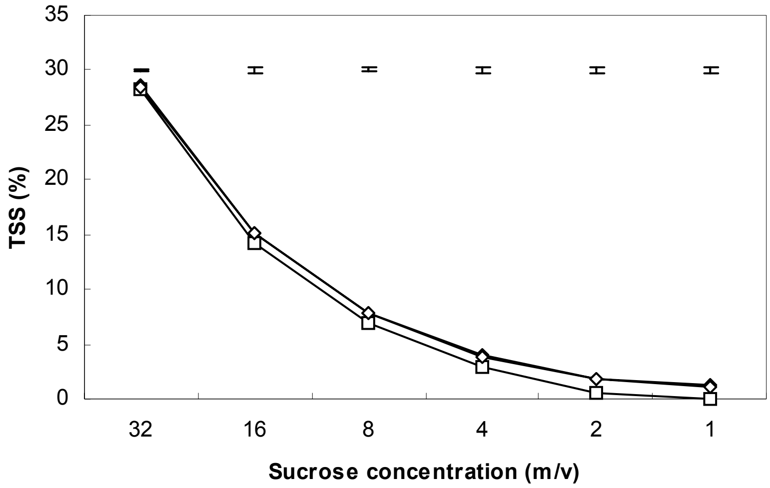


Figure 3.9 TSS (%) concentrations measured on pure AR-grade sucrose solutions with pocket 0-50%, pocket 0-30%, and digital refractometers. Keys for graphs: pocket 0-50% □, pocket 0-30% ♦, and digital ◊ refractometer; data are $\bar{x}$, n = 2, vertical bars show ± SEM, n = 6.

3.2.3.1 Conclusions

The pocket refractometer scaled 0-50% should not be used, as it is not precise enough. The same pocket refactometer scaled 0-30% and the digital refractometer should give the same values when used for banana TSS assessments. However this experiment needed to be repeated with more careful attention to solution preparation. As sucrose is hygroscopic it could make less concentrated than expected solutions when prepared on a w/v basis. To obtain anhydrous sucrose, which should yield exact solutions concentration-wise, drying of the sucrose granules before use is proposed

3.3 Checking of refractometers with dried AR-grade sucrose

3.3.1 Materials and Methods

One hundred g of AR-grade sucrose was dried for 24 h in a vacuum oven (Gallenkamp, UK) containing self-indicating silica gel and operated at a temperature of 37°C and a negative pressure of 800 mbar. This mass was re-weighed and dried again for 10 h. The sucrose grains had lost 0.09 g (9%) the first 24 hours and then just 0.01 g (1%) in the following 10 h. Various sucrose concentration solutions were then prepared as described in section 3.2.2. Refractometers were calibrated again at 0.00 with distilled water.

3.3.2 Results and discussion

Like in the first experiment, measured results were under the anticipated % TSS values (Figure 3.10). The pocket refractometer 0-30% and the digital refractometer gave very similar readings.

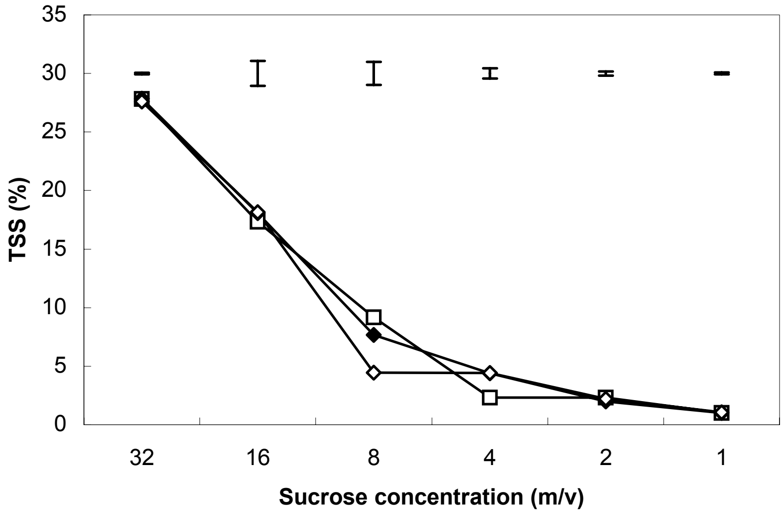


Figure 3.10. TSS (%) concentration measured on pure AR-grade dried sucrose solutions with pocket 0-50%, pocket 0-30%, and digital refractometers. Keys for graphs: pocket 0-50% □, pocket 0-30% ♦, and digital ◊ refractometer; data are $\bar{x}$, n = 3, vertical bars show ± SEM, n = 12.

3.3.2.1 Conclusion

It is recommended that the pocket scaled 0-30 % is used for the quality assessments of banana fruit. The reasons for underestimation by measurements of TSS values are unknown.

4 Experimental Part 2: Postharvest quality of conventionally and organically grown banana fruit from the Dominican Republic

4.1 Introduction

For the banana shipper, ripener and retailer, quality control is primarily a function of transport and storage conditions (Kashmire and Ahrens, 1992). For the grower, before the postharvest phase, quality control is based on field operations and conditions (Sommer and Arpaia, 1992). Optimal cultural management is needed in order to realise optimum quality as sought by, ultimately, the consumer. These criteria include fruit size, freedom from pest, disease, and physiological defects, and good visual appeal (Smith, 1995). These variables can influence the ripening process of the bananas in the country of consumption (Shewfelt, 1999). To obtain best quality fruits, the production management must consider the inputs (e.g. water and fertilisers) the natural conditions (e.g. climate, soils) and plant and fruit care (e.g. protection and harvest practices) (Bevererly *et al.*, 1992). Supermarkets perceive a strong need for quantitative measures of banana quality, such as TSS measurements to compliment qualitative assessment on the basis of skin colour (SH Pratt's and Co.). Moreover, some consumers notionally perceive a taste difference between conventionally and organically grown bananas (SH Pratt's and Co.). Thus, investigating methods of measuring TSS and comparing conventionally and organically grown banana fruit was strongly needed.

TSS levels and changes in banana fruit from nearby organically and conventionally managed farms in the same country are examined for serial harvests over part of the year as climate changed from winter to summer conditions.

4.2 Material and Methods

4.2.1 Fruit

Conventionally (plantation 57) and organically (plantation 11) grown green mature (colour stage 1; SH Pratt's & Co. colour chart) Cavendish banana fruit var. Grand Nain from nearby plantations in the Dominican Republic were supplied at different times of the season (Table 4.1, SH Pratt's & Co.).

Upper banana fingers from hands from 20 different boxes were chosen for each plantation and for each "time of season" to maximise randomness of the fruit tested. Mustaffa *et al.,* (1998) reported significant differences in quality of different hands and different fingers portions from the same bunch. Three hundred and eighty green banana fruit for quality assessments and sensory analysis, respectively were obtained in total. Of these 280 and 60 of the best ones were used for quality assessment and sensory analysis, respectively. Fruits were initially stored at 15°C for 2 days as preparation for assessment was carried out. Fingers were cut from the stem and left 2 h to let the latex dry, labelled and arranged randomly in open apple trays.

Table 4.1 Harvest details of fruit used in experiments A, B, C, D, E, and F. (SH Pratt's & Co.2000)

Harvest	Harvest week	Collect date	Season
A	04 (22-28/01/01)	12/02/01	winter
B	06 (05-11/02/01)	29/02/01	winter
C	10 (05-11/03/01)	28/03/01	winter
D	17 (23-29/04/01)	14/04/01	summer
E	20 (14-20/05/01)	05/06/01	summer
F	21 (28/05-03/06/01)	22/06/01	summer

4.2.1.1 Fruit management

Fruit used in this experiment came from the Dominican Republic. The Dominican Republic and Mexico have become the world's leading exporters of fresh organic banana fruit accounting for some 75% of world supply (De Haen, 1999). They were imported by the biggest European importer Savid GmbH (Eurofruit, 2001). Fruit from plantation 57 and 11 are conventionally and organically grown fruits, respectively. Both plantations are situated in the North West in Mao, 40 km from Santiago. Climate and plantation management are summarised in Figure 4.1 and Table 4.2, respectively.

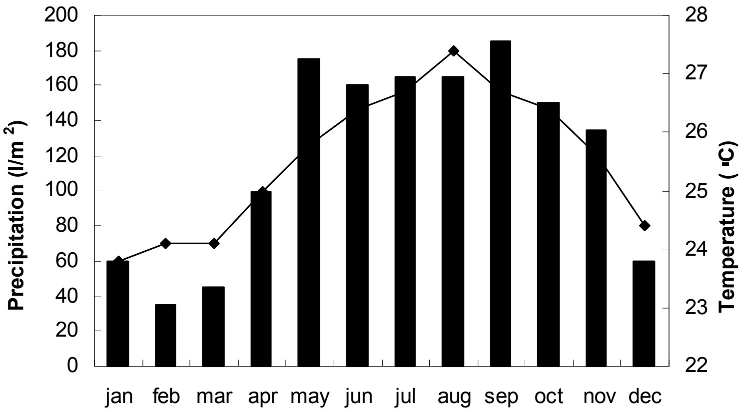


Figure 4.1 Monthly averages of temperatures (°C) ♦ and precipitation (l/m^2) █ for the Santiago station in the Dominican Republic in 1999. (source: from Meteo France internet site).

Table 4.2 Cultural management comparison for plantations 57 and 11 in the Dominican Republic (source: SH Pratt's & Co. audits).

	Plantation 57	**Plantation 11**
Field and plant		
Source of the plant	suckers	rejects
Age of plantation (years)	6	8
Density	1920 plt/ha	2240 plt/ha
Planting	linear	quinconce
Type of soil	alluvial	alluvial
Uniformity of the plots	yes	yes
Irrigation		
Type	inundation	inundation
Source of water	river	river
Type of drainage	gravity	gravity
Fertilisation based on soil and leaf analysis		
Type	15-6-25 N-P-K-Zn	compost (Biofer) and minerals (sulpomag: sulfate, potasium and magnesium)
Frequency	every 35/45 days	once every 2 months
Cultural practices		
Thining	false+2	false+2
Early sleeve used	yes	yes
Impregnated sleeve	yes	no
Weed control	mechanical	mechanical
Fungus control	chemical : Tilt (propiconazole), Calixie (thridemorph), Benlate (benomyl), Dithane (mancozeb)	biological
Nematode control	no	biological
Pest control	chemical: impregnated sleeve, Dursban (chloropyriphos)	bological
Harvest system		
Age control, coloured ribbons and grade checked	yes	yes
Postharvest quality		
Application of fungicide	chemical: Befor (bitertanole) or Nertek (thiabendazol)	biological: citric acid

4.2.2 Ethylene treatment

Day 0 was the designated day when ripening was commenced. On day 0, fruit stored at 20°C in two (harvests A and B) or three (harvests C, D, E and F) 340 L capacity airtight boxes received an ethylene shot dose of 100 µL/L. Ethylene was quantified as described in the first experiment (see section 3.2.2). After day 2, fruit were moved in ambient air at 20°C ±1°C and 60 ±10% relative humidity.

4.2.3 Fruit quality attributes

Quality assessments of fruit length, diameter, weight, colour, TSS, TA and starch staining were made. Fruit length and diameter were measured on day-1. For the latter parameters, measurements on samples were taken every 2 days for 12 days (n = 20 individual fruit replicates) as in experimental part 1 (section 3.2.2). TSS, TA, and starch staining were assessed on pulp from the middle section of fruit. TSS was measured with the same pocket 0-30% refractometer. Methods and data analysis were as described in experimental part 1 (section 3.2.3) unless otherwise described.

Pulp firmness was measured with a Mecmesin Advanced Force Gauge (AFG 500 N); resolution 0.1 N with an 8 mm diameter probe (Figure 4.2). This device was mounted onto the cross-head of a conventional Instron Universal Testing machine model 1122. Head speed was set at 50 mm/min. Firmness was expressed as the maximum force (N) required until tissue failure. The firmness was measured 2 cm away from the middle of the fruit.

Figure 4.2 Pulp firmness assessment on banana fruit.

4.2.3.1 Sensory analysis

A lot of different tests have been done on the banana's physical and chemical attributes. It is interesting to have an idea of the English consumers' taste using a sensory analysis. A discrimination test, the triangle test was chosen (Roland *et al.*, 1986). The Discrimination or Difference test is used to compare 2 or more products indicating whether any differences are perceived. The triangle test is used to determine whether an unspecified sensory difference exists between two treatments. Sensory analysis was by the triangle test to determine whether untrained panellists could determine a difference between conventionally and organically grown banana fruit. As far as possible, the same 30 panellists from the University campus with a wide range of sex, age and job were chosen for harvest time C, D, E, and F. It is recommended to chose at least 10 (Frijters, undated) or between 18 and 24 (Roland *et al.,* 1986) panellists, so 30 were chosen in order to have a big enough sample. Banana fruit used for sensory analysis in harvests C, D, E, and F were ethylene gas treated along with the other fruit used for quality assessments.

Taste panels were run on day 7, when bananas were at colour stage 7 (figure 2.3). Before each code test, banana fruit were cut fresh into slices of the same size and placed evenly on code numbered white cardboard plates. Tasting orders of OOC, OCO, COO, CCO, COC, OCC where O is for organic and C is for conventional grown fruit were adopted to avoid any bias (Pangborn, undated). Panellists had to complete the questionnaire shown in Figure 4.3. The "no-perceivable-difference option" as opposed to the "forced choice option" was chosen so as to avoid forcing people who could not taste any difference to say something they could not perceive. The test enabled panellists to tell whether a difference existed, how they would describe the difference, and how large was the difference. Each assessor did the test in the same room, one at a time, with fresh water available for mouth rinsing. Results were analysed ($P \leq 0.05$) using the statistical chart given by Larmond (1977). For 30 panellists, 16 correct answers were needed in order to reject the null hypothesis which was "there is no difference between conventionally and organically grown bananas".

QUESTIONNAIRE FOR
TRIANGLE TEST

NAME__________________DATE__________________

PRODUCT__________________________________

Two of these three samples are identical, the third is different.

1. Taste the samples in the order indicated and identify the odd sample.

Code	Check odd sample
___	________________
___	________________
___	________________

2. Indicate the degree of difference between the duplicate samples and the odd sample.

   Slight __________
   Moderate __________
   Much __________
   Extreme __________

3. Acceptability:

   Odd sample more acceptable __________
   Duplicates more acceptable __________

4. Comments:

Figure 4.3 Questionnaire for triangle test from Larmond (1977).

4.3 Results

4.3.1 Harvest A, week 04 (22-28/01/01)

There were strong significant differences ($P \leq 0.05$) for both length and diameter between conventionally and organically grown banana fruit samples (Table 4.3).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 0, 2, 4, 6, 8, 10 and 12, days 0, 6, 8, 10 and 12, days 2 and 12, and days 10 and 12, for L* (Figure 4.4A), H° (Figure 4.4B), FW (Figure 4.4C) and firmness (Figure 4.4D), respectively. L* increased between day 0 and day 6, where the maximum L* was reached, and fell after day 6. L* was slightly higher for conventionally grown fruit than for organically grown fruit. H° decreased markedly from day 0 until day 6 and then continued to decrease at a slower rate until day 12. H° was marginally lower for conventionally grown bananas on days 0 and 2, and slightly higher from days 6 to 12. FW decreased consistently from day 0 to day 12. On day 2, FW was marginally lower for conventionally grown banana fruit but was slightly higher on day 12. Firmness decreased dramatically between day 0 and day 2, and thereafter, decreased only slightly between days 2 and 12. On days 10 and 12, firmness was slightly higher for conventionally grown fruit.

There were also minor but significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 2, 4, and 8, and on days 4, 8, 10 and 12 for TA (Figure 4.4E) and starch staining (Figure 4.4F), respectively. TA increased between day 0 and day 4 and between day 0 and day 8 for organically and conventionally grown banana fruit, respectively, and decreased thereafter. Starch staining decreased markedly after day 2 and was marginally less for organically grown bananas.

There were significant differences ($P \leq 0.05$) on days 2, 4, 6, 8, and 10, and on days 0, 2, 4, 6, 8, 10, and 12 for TSS measurement between conventionally and organically grown banana fruit (Figure 4.4G) and between the undiluted and diluted method of TSS measurements (Figure 4.4H). TSS measurement increased consistently between days 0 and 6, and, thereafter, continued to increase but at a slower rate between days 6 and 12. Organically grown fruit had slightly higher TSS measurement than conventionally grown fruit. The undiluted sampling method gave significantly ($P \leq 0.05$) higher TSS measurements than the diluted method throughout the experiment.

Table 4.3 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\bar{x}$ ± SE, n = 140.

	Conventional	Organic
Length (cm)	20.88 (± 0.13)	19.70 (± 0.10)
Diameter (mm)	35.43 (± 0.20)	33.23 (± 0.14)

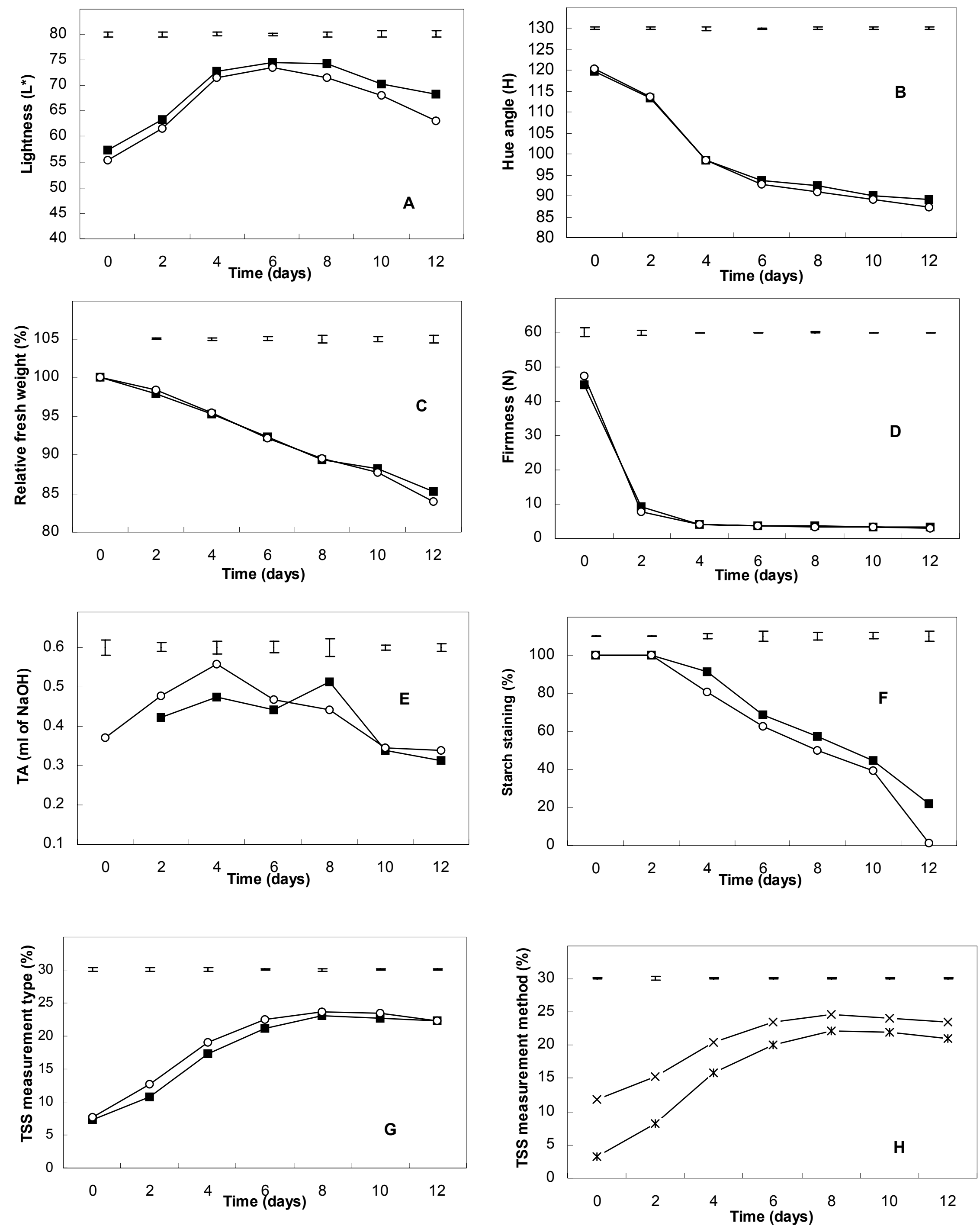


Figure 4.4. Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and ⁎ diluted method, data are $\bar{x}$, n = 20; vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.1).

4.3.2 Harvest B, week 06 (05-11/02/01)

There were no significant differences for length and diameter between conventionally and organically grown banana fruit (Table 4.4).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 6 and 12, and days 2, 4, 6, 8 and 10 for L* (Figure 4.5A), and FW (Figure 4.5C) respectively. There were no significant differences ($P \leq 0.05$) for H° (Figure 4.5B) and firmness (Figure 4.5D). L* increased between day 0 and day 4, where the maximum L* was reached. On day 6, conventionally grown bananas had slightly lower L* than organically grown bananas. H° decreased markedly from day 0 until day 6, then continued to decrease but at a slower rate until day 12. FW decreased consistently from day 0 to day 12. Conventionally grown bananas had slightly lower FW than organically grown bananas. Firmness decreased dramatically between day 0 and 2, and decreased slightly between day 2 and 12.

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 0, 2, and 6, and on day 12 for TA (Figure 4.5E) and starch staining (Figure 4.5F), respectively. TA increased between days 0 and 4, decreased between days 4 and 6, increased again between days 6 and 8, and then decreased thereafter. Starch staining decreased markedly after day 2 and was marginally less for conventionally grown bananas.

There were significant differences ($P \leq 0.05$) on day 12 throughout the experiment for TSS measurement between conventionally and organically grown banana fruit (Figure 4.5G) and for between the undiluted and the diluted method (Figure 4.5H), respectively. TSS measurement increased consistently between days 0 and 4, then continued to increase but more slowly between days 4 and 10, and then decreased slightly after day 10. The undiluted sampling method gave significant ($P \leq 0.05$) higher TSS measurement than the diluted method.

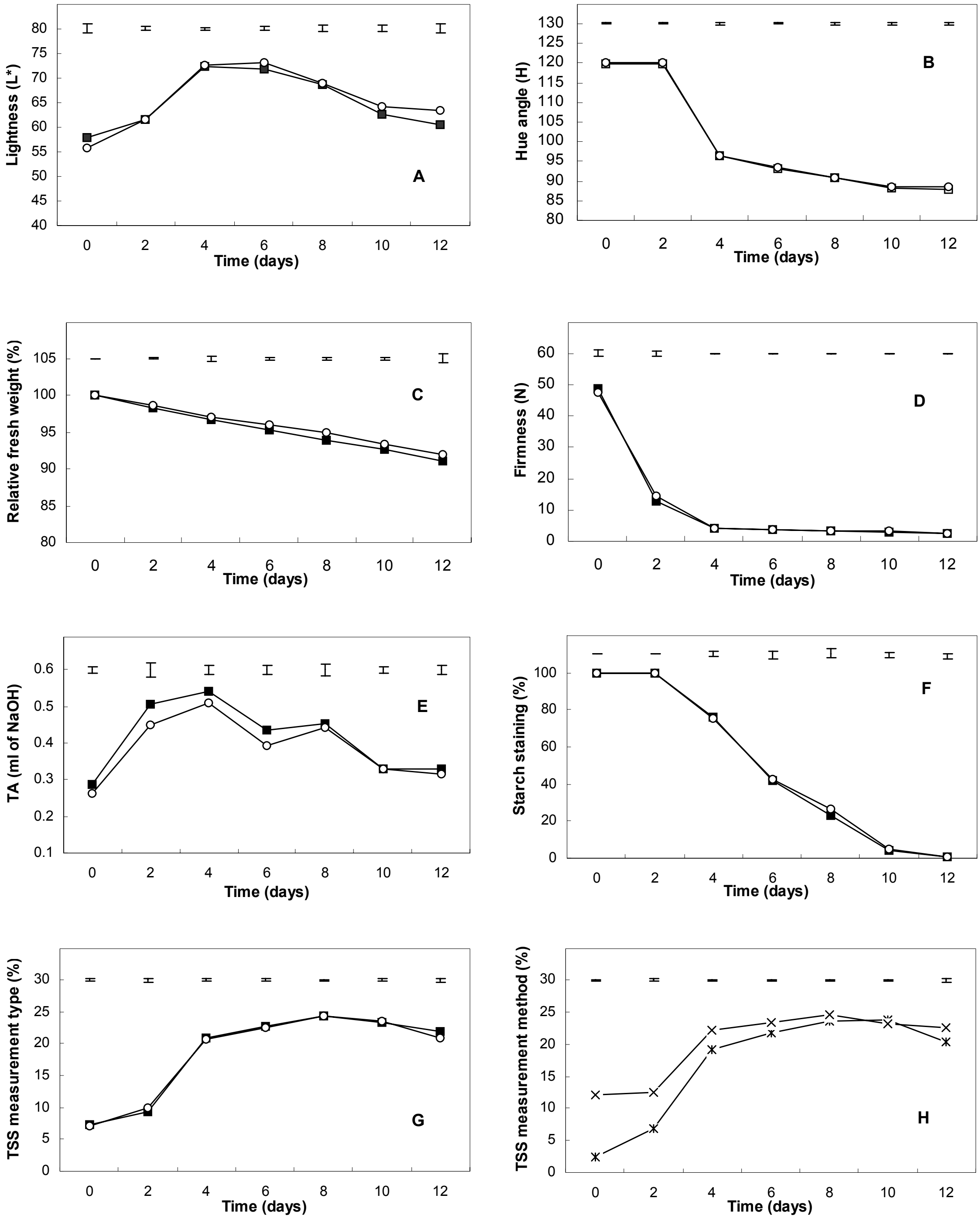


Figure 4.5 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and ⋇ diluted method; data are $\overline{x}$, n = 20, vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.2).

Table 4.4 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green), data are $\bar{x}$ ± SE, n = 140.

	Conventional	Organic
Length (cm)	20.24 (± 0.12)	20.53 (± 0.12)
Diameter (mm)	35.10 (± 0.12)	35.43 (± 0.13)

4.3.3 Harvest C, week 10 (05-11/03/01)

There were no significant differences ($P \leq 0.05$) for length but significant differences ($P \leq 0.05$) for diameter between conventionally and organically grown banana fruit (Table 4.5).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 6, 8 and 10, days 6, 8, and 10, and day 2 for L* (Figure 4.6A), H° (Figure 4.6B), and FW (Figure 4.6C), respectively. There were no significant differences ($P \leq 0.05$) for firmness (Figure 4.6D). L* increased between days 0 and 6 and then decreased between days 6 and 12. H° decreased markedly from day 0 until day 6 and then continued to decrease but at a slower rate until day 12. On day 6, 8 and 10, conventionally grown bananas had slightly higher L* and H° values than organically grown bananas. FW decreased regularly from day 0 to day 12. Firmness decreased dramatically between days 0 and 2 and decreased slightly between day 2 and 12.

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 2 and 10 and on days 4, 6 and 10 for TA (Figure 4.6E) and starch staining (Figure 4.6F), respectively. TA increased between days 0 and 4 and decreased thereafter. Starch staining decreased markedly after day 2. On days 4, 6, and 10. starch staining was slightly higher for conventionally grown bananas.

There were significant differences ($P \leq 0.05$) on day 2 and throughout the experiment for TSS measurement between conventionally and organically grown banana fruit (Figure 4.6G) and between the undiluted and the diluted method (Figure 4.6H), respectively. TSS measurement increased consistently between days 0 and 6, then continued to increase but more slowly between days 6 and 8, and slightly decreased thereafter. The undiluted method gave significantly ($P \leq 0.05$) higher TSS measurement than the diluted method.

Table 4.5 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\bar{x} \pm$ SE, n = 140.

	Conventional	Organic
Length (cm)	21.20 (± 0.14)	21.22 (± 0.14)
Diameter (mm)	34.40 (± 0.22)	34.70 (± 0.16)

4.3.3.1 Sensory analysis

Out of thirty people, fourteen people correctly perceived difference between conventionally and organically grown fruit (Appendix 4.3.2). Thirteen people did not get the right difference between conventionally and organically grown fruit. Three people didn't see any difference at all. Out of the fourteen people, four preferred the conventionally grown fruit and ten preferred the organically grown fruit. The results were not significant ($P \leq 0.05$).

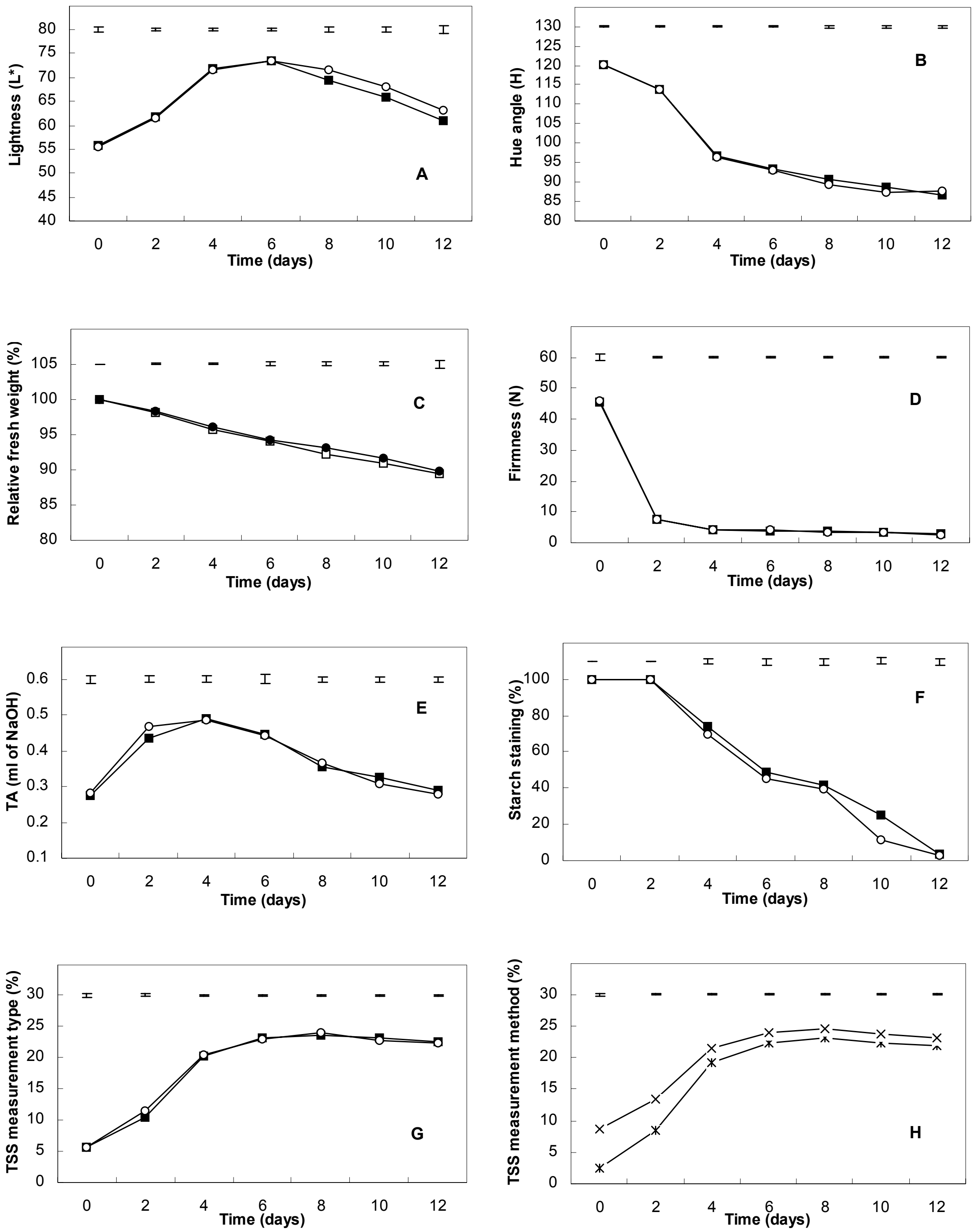


Figure 4.6 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and ⁎ diluted method; data are $\overline{x}$, n = 20, vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.3.1).

4.3.4 Harvest D, week 17 (23-29/04/01)

There were no significant differences ($P \leq 0.05$) for length and significant differences ($P \leq 0.05$) for diameter between conventionally and organically grown banana fruit (Table 4.6).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on day 12, days 0, 2, 4, 6, 8, 10 and 12, days 8, 10 and 12, and days 10 and 12 for L* (Figure 4.7A), H° (Figure 4.7B), FW (Figure 4.7C) and firmness (Figure 4.7D), respectively. L* increased between days 0 and 4, stabilised between days 4 and 6, and decreased thereafter. H°decreased markedly from day 0 to day 4 and then continued to decrease but slowly until day 12. H° was higher for conventionally grown bananas throughout the experiment. FW decreased consistently from day 0 to day 12. After day 8, conventionally grown bananas had marginally lower FW than organically grown bananas. Firmness decreased dramatically between days 0 and 2 and decreased slightly thereafter between days 2 and 12.

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 0 and 2, and day 6 for TA (Figure 4.7E) and starch staining (Figure 4.7F), respectively. TA increased between days 0 and 4 and decreased thereafter. Starch staining decreased markedly after day 2.

There were significant differences ($P \leq 0.05$) for TSS measurement on day 2 and throughout the experiment between conventionally and organically grown banana fruit (Figure 4.7G) and between the undiluted and the diluted method, respectively (Figure 4.7H). The undiluted method gave significant higher TSS measurement than the diluted method.

Table 4.6 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\bar{x}$ ± SE, n = 140.

	Conventional	Organic
Length (cm)	21.41 (± 0.13)	21.40 (± 0.11)
Diameter (mm)	35.54 (± 0.16)	35.54 (± 0.11)

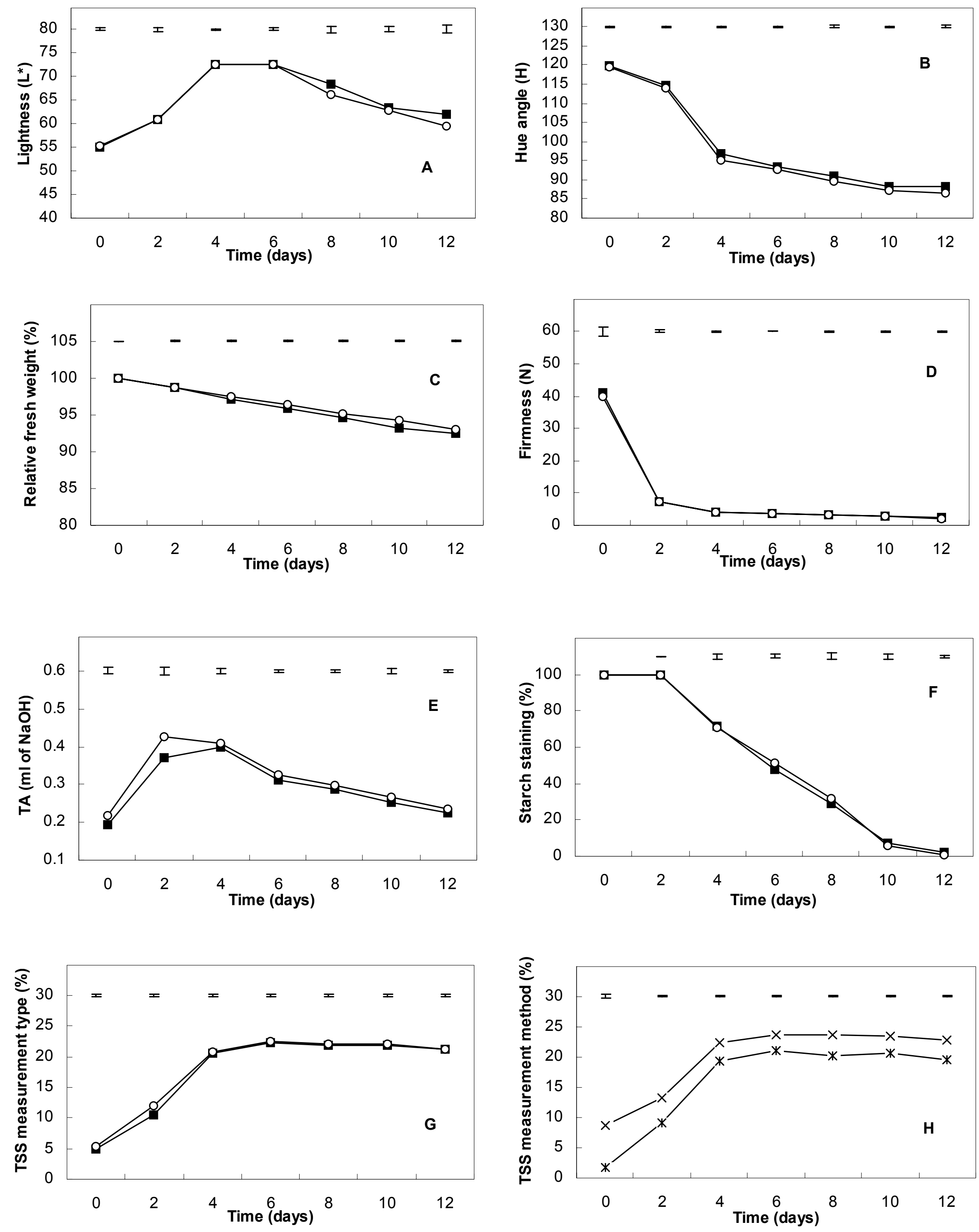


Figure 4.7 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and ⁎ diluted method; data are $\overline{x}$, n = 20, vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.4.1).

4.3.4.1 Sensory analysis

Out of thirty people, eighteen people correctly perceived difference between conventionally and organically grown fruit (Appendix 4.4.2). Thirteen did not get the right difference between conventionally and organically grown fruit. Out of the eighteen people, ten preferred the conventionally grown fruit and eight preferred the organically grown fruit. The result was significant ($P \leq 0.05$).

4.3.5 Harvest E, week 20 (14-20/05/01)

There were no significant differences ($P \leq 0.05$) for length and significant differences ($P \leq 0.05$) for diameter between conventionally and organically grown banana fruit (Table 4.7).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 2, 4, 8, and 12, days 2, 4, 6, 8, and 12, day 4, 6, 8, 10 and 12, and day 8, 10 and 12 for L* (Figure 4.8A), H° (Figure 4.8B), FW (Figure 4.8C) and firmness (Figure 4.8D), respectively. L* increased between days 0 and 4, lowered between days 4 and 10 and increased again after day 10. On days 2 and 4, then on days 8 and 12, conventionally grown bananas had slightly lower and slightly higher, respectively, L* values than organically grown bananas. H° decreased a lot between days 0 and 4 then continued to decrease but at a slower rate until day 12. FW decreased consistently from day 0 to day 12.

Firmness decreased dramatically between day 0 and 2 and decreased slightly between day 2 and 12. Conventionally grown bananas had slightly higher H° and slightly lower FW than organically grown bananas.

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on day 0, and no significant differences ($P \leq 0.05$) for TA (Figure 4.8E) and starch staining (Figure 4.8F), respectively. TA increased slightly between days 0 and 2, and decreased thereafter. Starch staining decreased markedly between days 0 and 12.

There were significant differences ($P \leq 0.05$) for TSS measurement on days 0, 2, and 12 and throughout the experiment between conventionally and organically grown banana fruit (Figure 4.8G) and between the undiluted and the diluted TSS measurement methods (Figure 4.8H), respectively.

Table 4.7 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\bar{x}$ ± SE, n = 140.

	Conventional	Organic
Length (cm)	21.92 (± 0.10)	21.87 (± 0.10)
Diameter (mm)	36.16 (± 0.13)	35.18 (± 0.11)

4.3.5.1 Sensory analysis

Out of thirty people, fifteen people correctly perceived a difference between conventionally and organically grown fruit (Appendix 4.5.2). fourteen people did not get the right difference between conventionally and organically grown fruit. One person didn't see any difference at all. Out of the fifteen people, seven preferred the conventionally grown fruit and eight preferred the organically grown fruit. The result was not significant ($P \leq 0.05$).

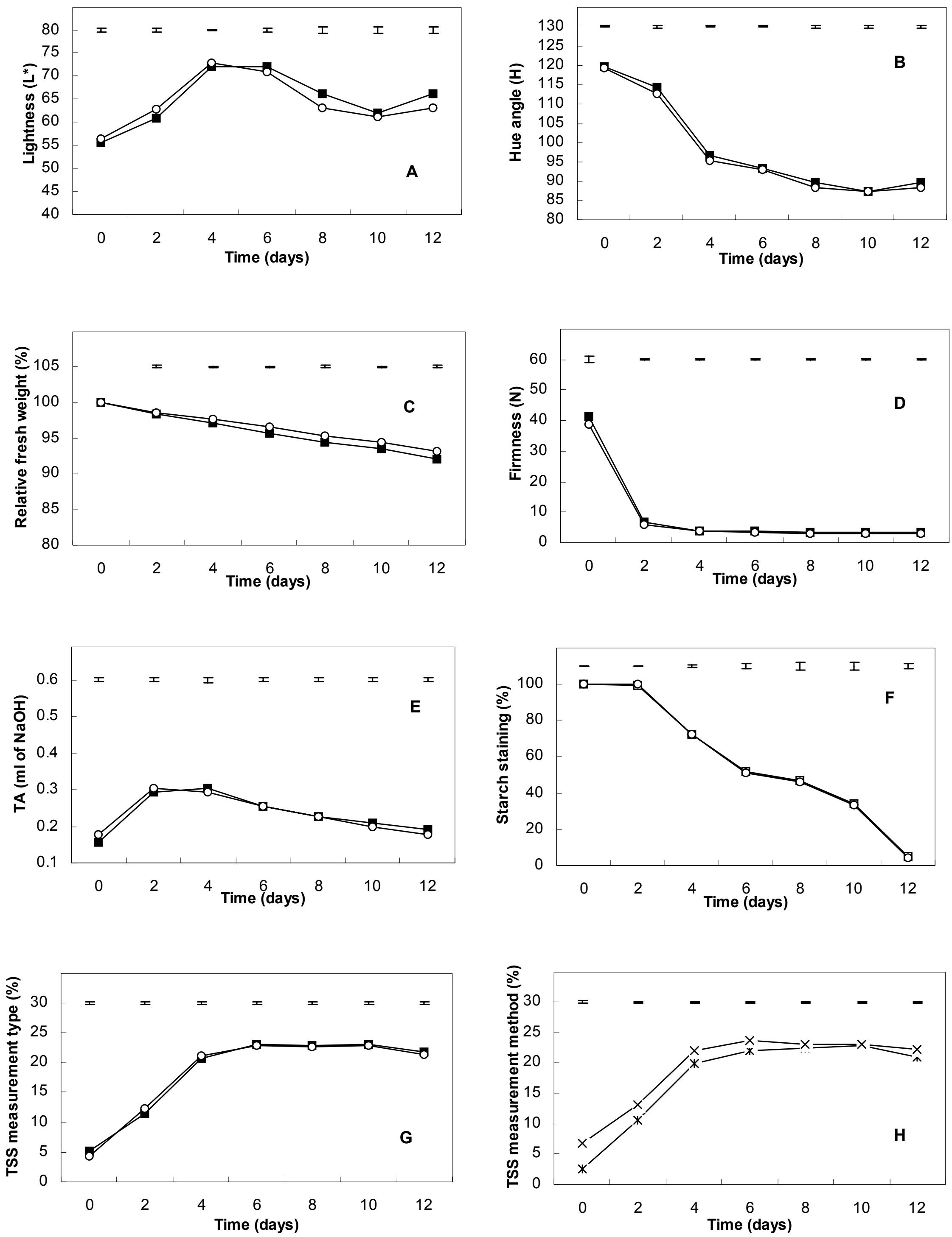


Figure 4.8 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Key for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and * diluted method; data are $\overline{x}$, n = 20, vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.5.1).

4.3.6 Harvest F, week 21 (28/05-03/06/01)

There were significant differences ($P \leq 0.05$) for length and diameter between conventionally and organically grown banana fruit (Table 4.8).

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 0, 2, and 4, days 2 and 4, and days 4, 8, and 10 for H° (Figure 4.9B), FW (Figure 4.9C), and firmness (Figure 4.9D), respectively. There were no significant differences ($P \leq 0.05$) for L* (Figure 4.9A). L* increased between days 0 and 6 and thereafter decreased. H° decreased markedly between days 0 and 4 then continued to decrease but at a slower rate until day 12. On days 0, 2 and 4, conventionally grown bananas had slightly lower H° than organically grown bananas. FW decreased regularly from day 0 to day 12. Firmness decreased dramatically between day 0 and 2 and then decreased slightly between days 2 and 12.

There were significant differences ($P \leq 0.05$) between conventionally and organically grown banana fruit on days 4 and 6 for TA (Figure 4.9E) but no significant differences ($P \leq 0.05$) for starch staining (Figure 4.9F). TA increased between days 0 and 6, and decreased thereafter. Starch staining decreased markedly between days 0 and 12.

There were no significant differences ($P \leq 0.05$) for TSS measurement between conventionally and organically grown banana fruit (Figure 4.9G) and strong significant differences ($P \leq 0.05$) during the whole experiment between the undiluted sampling method and the diluted method (Figure 4.9H).

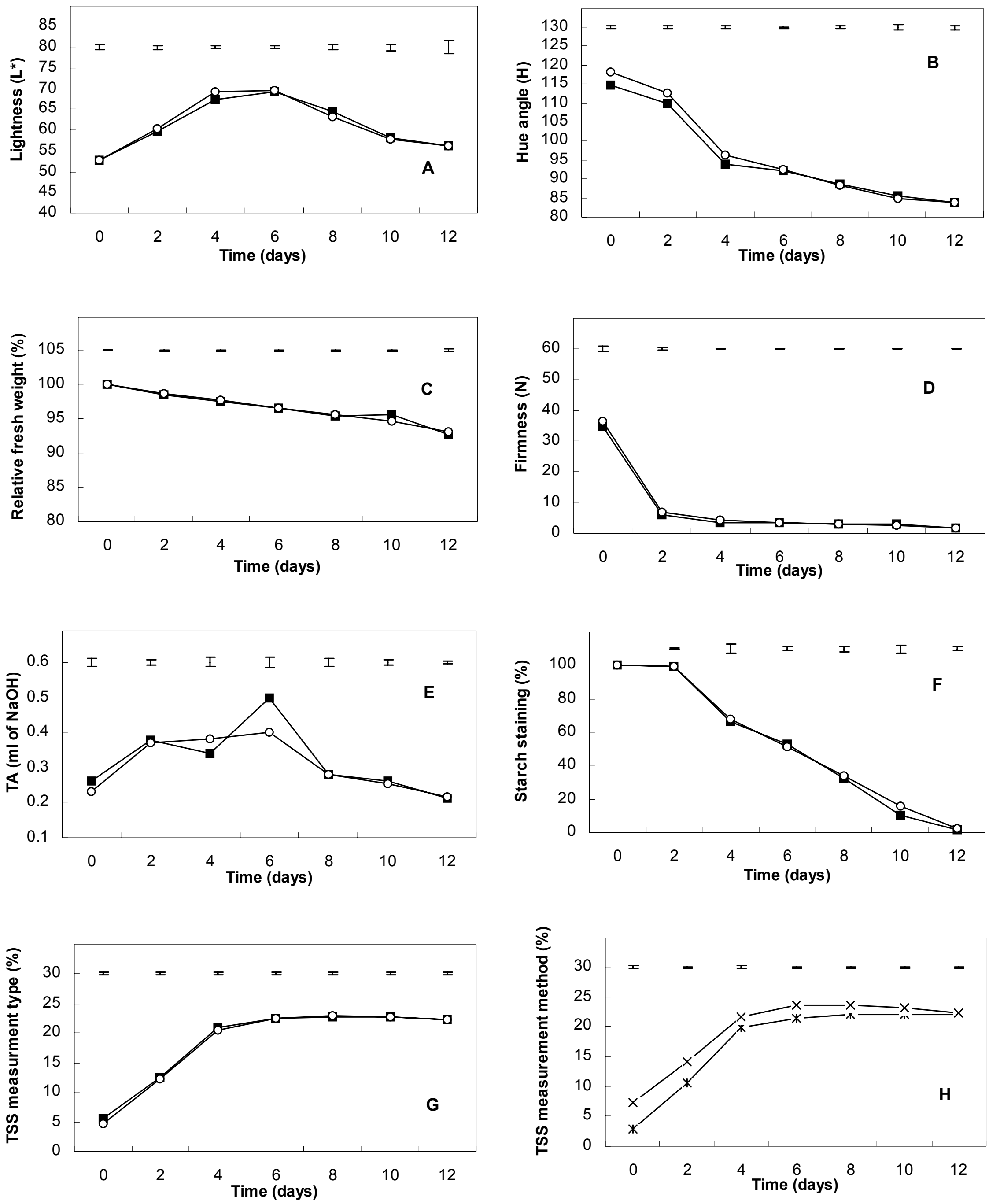


Figure 4.9 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured every second day during shelf life. Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and ⁎ diluted method; data are $\overline{x}$, n = 20, vertical bars show ± SEM, n = 40 (for ANOVA see Appendix 4.6.1).

Table 4.8 Length and diameter of conventionally and organically grown banana fruit at colour stage 1 (all green); data are $\bar{x}$ ± SE, n = 140.

	Conventional	Organic
Length (cm)	21.92 (± 0.10)	22.35 (± 0.08)
Diameter (mm)	37.95 (± 0.13)	36.71 (± 0.12)

4.3.6.1 Sensory analysis

Out of thirty people, thirteen people correctly perceived difference between conventionally and organically grown fruit (Appendix 4.6.2). Fifteen people did not get the right difference between conventionally and organically grown fruit. Two people didn't see any difference at all. Out of the thirteen people, two preferred the conventionally grown fruit and eleven preferred the organically grown fruit. The result was not significant ($P \leq 0.05$).

4.3.7 Discussion

4.3.7.1 Size

Apart from harvest B, there were differences in diameter between organically and conventionally grown banana fruit. The organically grown fruit were significantly bigger in diameter than conventionally grown fruit. Conventionally grown banana fruit were class I, whereas organically grown banana fruit were class II (Ruel, pers.comm.). Although, the biggest class II banana fruit were chosen in order to match as far as possible the size of class I banana fruit.

4.3.7.2 Skin colour

L* values tended to increase between days 0 and 4, then to decrease thereafter. H° decreased dramatically between days 0 and 4 and then at a slower rate thereafter. There were only slight differences between conventionally and organically grown fruit. As they ripen, banana fruit develop a bright yellow colour (stage 6, all yellow) as chlorophyll is degraded and carotenoids become visible (Marriott and Lancaster, 1983; Stover and Simmonds 1987, Seymour, 1993). Thereafter brown spots (senescent) appear on the skin as fruit become overripe (Agravante *et al*., 1990).

4.3.7.3 Relative fresh weight

FW decreased consistently throughout the experiment from 100% on day 0 to about 90% on day 12. There were only marginal differences between conventionally and organically grown fruit. Banana fruit loose moisture from the peel and the pulp due to respiration and transpiration and (Stover and Simmonds, 1987).

4.3.7.4 Pulp firmness

Firmness decreased dramatically between days 0 and 2 and then continued to decrease at a slower rate thereafter. There were very slight differences between conventionally and organically grown fruit. This rapid softening corresponds to an interconversion of pectic substances (Marriott and Lancaster, 1993).

4.3.7.5 Titratable acidity

TA showed an inconsistent pattern of increase and decrease. There was very little difference between conventionally and organically grown fruit. TA increased as the banana fruit ripened and then decreased, as the fruit became overripe. Sanchez *et al.* (undated) also found this pattern during ripening of Montecristo banana where acidity increased during the first six days after ripening and decreased thereafter.

4.3.7.6 Starch staining

Starch staining tended to decrease consistently from 100% on day 0 to almost nil on day 12. There were only slight differences between conventionally and organically grown fruit. During the preclimacteric, starch content is evident (Cordenunsi and Lajolo, 1995). The rate of degradation is slow initially and then increases as the banana ripen and then during the postclimacteric, no starch is detected any more (Garcia and Lajolo, 1988).

4.3.7.7 TSS

TSS measurements always increased consistently between days 0 and 6. After this time tended to stabilise and even to decrease towards days 10 and 12. Increase of TSS is an important characteristic of hydrolysis of starch into soluble sugars such as sucrose, glucose and fructose (Lizana, 1976; Marriott *et al.*, 1981; Kanellis *et al.*, 1989; Agravante *et al.*, 1990; Chang and Hwang, 1990; Cordenunsi and Lajolo, 1995). There were marginal differences between conventionally and organically grown fruit, but there were consistent significant differences between the undiluted and the diluted method of TSS measurements. This result is vital for future TSS measurement in industry.

4.3.7.8 Sensory analysis

Overall, out of four sensory analysis tests, only one gave the result that people could perceive a difference between conventionally and organically grown fruit. Moreover, the significant number of 16 out of 30 panellists needed was only just reached. Importantly of the people who could taste a difference, only half of them preferred the organically grown fruit. In previous reports from Sauve (1998) and in BBC News (2000), only 14% and 29% people stated that taste is the reason for buying organically grown fruit and vegetables. It was reported that the people were much more concerned about health.

4.3.7.9 Results over harvests

Over successive harvests there was no marked difference in length (Figure 4.10A) or diameter (Figure 4.10B) between conventionally and organically grown banana fruit Over successive harvests there were no marked differences in lightness (Figure 4.11A), hue angle (Figure 4.11B), fresh weight (Figure 4.11C), firmness (Figure 4.11D), titratable acidity (Figure 4.11E), starch staining (Figure 4.11F) and TSS measurement type (Figure 4.11G). There was however, significant differences between the measured TSS by different methods (Figure 4.11H).

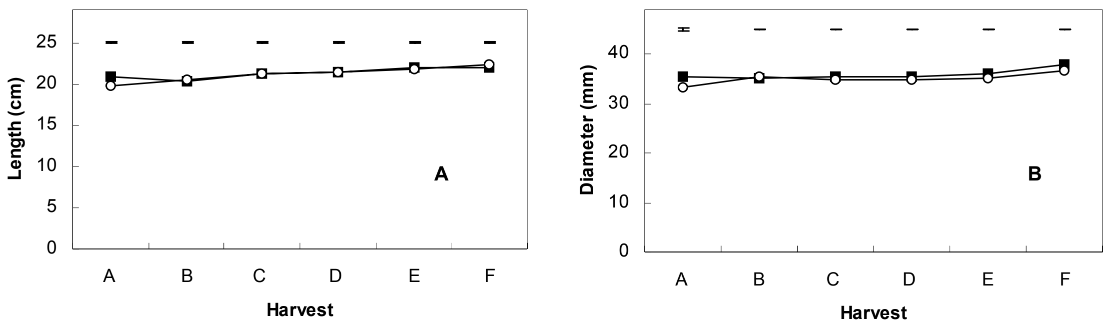


Figure 4.10 Changes in A. length and B. diameter measured on day 0 at colour stage 1 (all green) for the 6 harvests A (22-28/Jan), B (05-11/ Feb), C (05-11/Mar), D (23-29/Apr), E (14-20/May), and F (28/Jun-03/Jul). Keys for graphs: conventionally ■ and organically ○ grown banana fruit; data are $\overline{x}$, n = 20, vertical bars show ± SE, n = 40.

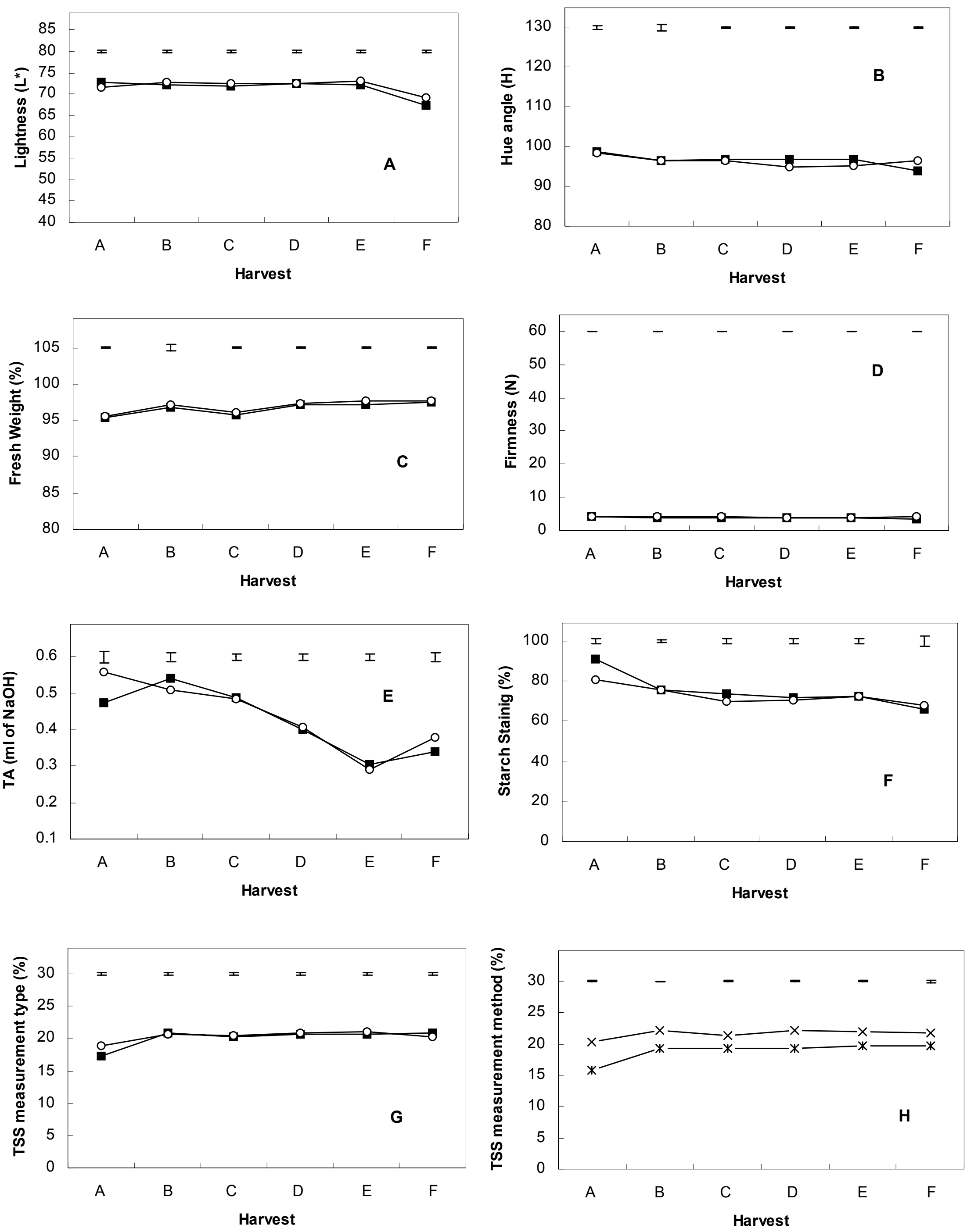


Figure 4.11 Changes in A. L*, B. H°, C. FW (%), D. firmness (N), E. TA (ml of NaOH), F. starch staining (%), and G. and H. TSS (%) measured on day 4 at colour stage 6 (all yellow) for the 6 harvests A (22-28/Jan), B (05-11/ Feb), C (05-11/Mar), D (23-29/Apr), E (14-20/May), and F (28/Jun-03/Jul).

Keys for graphs: conventionally ■ and organically ○ grown banana fruit, x undiluted and $\divideontimes$ diluted method; data are $\bar{x}$, n = 20, vertical bars show ± SEM, n = 40.

4.3.7.10 Conclusions

There were no consistent significant differences in quality attributes between conventionally and organically grown fruit from the same area in the Dominican Republic. There was however, strong significant difference between methods for TSS measurements. The undiluted method is inappropriate for TSS measurement on banana fruit.

5 General discussion

There were significant differences ($P \leq 0.05$) in size between the two lots of conventionally grown fruit from Costa Rica and organically grown fruit from the Dominican Republic. However, this difference was because of their class difference and does not reflect plantation management practices. Conventionally grown fruit were class I as opposed to organically grown fruit, which are always class II (Ruel, pers. comm.).

L* values of fruit skin increased until colour stage 6 (full yellow) and decreased thereafter (Figures 3.6A, 4.4A, 4.5A, 4.6A, 4.7A, 4.8A, and 4.9A). H° decreased markedly until fruit reached colour stage 6 (full yellow), and then continued to decrease at a slower rate (Figures 3.6B, 4.4B, 4.5B, 4.6B, 4.7B, 4.8B, and 4.9B). The colour stage changes are due to the breakdown of chlorophyll and the appearance of carotenoids that occur during ripening (Marriott and Lancaster, 1983; Stover and Simmonds, 1987, Seymour, 1993).

FW decreased consistently over the experimental period of 12 days. This was possibly due to loss of moisture from the pulp and the peel as reported by Stover and Simmonds (1987) (Figures 3.6C, 4.4C, 4.5C, 4.6C, 4.7C, 4.8C, and 4.9C). Firmness decreased dramatically during the early colour change period and then decreased at a very low rate thereafter (Figures 4.4D, 4.5D, 4.6D, 4.7D, 4.8D, and 4.9D). This decline corresponds to tissue softening by pectin solubilisation in cell wall that occurs during banana fruit ripening (Hultin and Levine, 1963, Smith *et al*., 1990).

TA tended to increase during ripening and decrease thereafter (Figures 3.7A, 3.7B, 4.4E, 4.5E, 4.6E, 4.7E, 4.8E, and 4.9E). However, this pattern of change was not consistent between experiments. The ripening banana can show an increase in acidity that may be due to the increase in malic acid (John and Marchal, 1995).

Starch staining decreased markedly during shelf life (3.7C, 3.7D, 4.4F, 4.5F, 4.6F, 4.7F, 4.8F, and 4.9F). This depicts one of the most important change that occurs during banana ripening, the hydrolysis of starch into sugar (Marriott *et al*., 1981;

Garcia and Lajolo, 1988; Agravante *et al.*, 1990, Chang and Hwang, 1990; Prahba and Bhagylaksmi, 1998) and as well as can conversion of carbohydrate to CO_2 by the process of respiration (Marriott *et al*., 1981). The pulp starch content can drop from 25% in the preclimacteric phase to less than 1% during the climacteric period (Cordenunsi and Lajolo, 1995). TSS increased markedly during ripening, this being mainly the result of hydrolysis of starch by amylase and glucosidase into sugars (Garcia and Lajolo, 1988; Agravante *et al*., 1990; Nascimento *et al*., 1997). Soluble sugars, synthesised by SPS and SS in banana fruit are mainly comprised of sucrose, glucose and fructose (Lizana, 1976; Marriott *et al*., 1981; Kanellis *et al*., 1989; Agravante *et al*., 1990; Chang and Hwang, 1990; Cordenunsi and Lajolo, 1995).

In the preliminary technique development experiments, there were significant differences ($P \leq 0.05$) between proximal, middle, and distal pulp tissue sampling positions. There were also significant differences ($P \leq 0.05$) between the undiluted and the diluted methods for TSS measurement. Testing of a pocket 0-30% refractometer, the same pocket refractometer but scaled 0-50% and a digital refractometer against sucrose solutions was conducted to directly compare the different devices for TSS measurement.

Between conventional and organic plantations in the Dominican Republic there were overall, only slight significant ($P \leq 0.05$) and largely inconsistent differences ($P \leq 0.05$) in L*, H°, FW, firmness, TA, starch staining and TSS. Sensory analysis showed that few people could not determine taste difference between conventionally and organically grown fruit. Moreover, in that proportion of tasters who did correctly determine a difference, only half of them said that they preferred the organically grown fruit. This finding supports the assertion that generally, the consumption of organic produce is rather a choice of health than a choice in taste (Sauve, 1998; BBC News, 2000).

5.1 Conclusion

With regard to industry quality assessment, improvement, the following conclusions are made: As TSS measurement varies (i.e. higher) towards the ends of banana fruit, pulp tissue for TSS measurement should be sampled in the middle. The conventional diluted method of TSS assessment is more appropriate than the novel undiluted method, which does not measure TSS precisely. The use of a pocket refractometer scaled 0-30% is well suited for TSS measurements.

With regard to organic versus conventional fruit: Significant differences ($P \leq 0.05$), when found, were usually only marginal in term of magnitude and were not consistent in across either harvest time or time of assessment during shelf life. Conventionally and organically grown fruit from the same area in the Dominican Republic showed similar postharvest qualities, including TSS. Sensory analysis confirmed that people could not taste a difference between these conventionally and organically grown banana fruit.

For future research, the following recommendations are made: Improving this study could be achieved by using organic versus conventional banana fruit from the same plantation if this were possible. Ideally, fruit of the same size would give more exact basis for comparing them. Sensory analysis could be expanded to be done when banana fruit are also at colour stage 4 and using larger numbers panel of panellists with more varied backgrounds. To extend this study, future research could also compare paired organic and conventional banana fruit samples from different countries. Consumers have also complained about “dollar banana” from Costa Rica being tasteless while Caribbean banana are tasteful (Ruel, pers. comm.). Furthermore, in extending this idea, future research could look at specific management effects relating to plantation size and individual cultural practices including those related to edaphic factors.

Appendix 1: Example of client's specification

OF-BAN-02-01 TESCO ORGANIC PRODUCE SPECIFICATION September 2000

All products and supplier sites must comply with UK Register for Organic Food Standards (UKROFS) as a minimum legal requirement.

1. Product : Fun Size Organic Bananas

2. Origin : Dominican Republic, Martinique

3. Varieties : Cavendish

4. Appearance : Clusters of sound, fresh, bright bananas. The crown should be sound and cleanly cut. Fruit should be evenly graded in a pack and ripened to a uniform colour.

   Note : As this line is organically grown, skin finish may not be as clean as conventional Bananas.

5. Colour Stage : Colour - stage 4

6. Defects : Unacceptable - Nil tolerance
   Presence of pest, chemical residue or other extraneous material.
   Presence of off flavours, aromas or taints.

   Minor - As per Tesco Conventional Banana Manual
   - Target % 60% A, 40% B & C, with max 20% of C

   Note : Organic Bananas may show some light smooth speckling of the skin - do not confuse this with thrips which will be small rough, raised lumps on the skin surface.

7. Temperature : Target pulp temperature range on delivery 14 - 16 deg.C
   Acceptable pulp temp. range on delivery 13 - 18 deg.C

8. Size/Count : Number of pods/bag = 6
   All combinations possible with a maximum of 2 single pods per bag.

   Length of pod = 14 - 19cm

   15 packs/outer

9. Date Code : Depot + plus 2 days

10. Packaging : Fruit packed into clear bag perforated to hold product.
    Bag twisted tight and sealed.
    OR
    Fruit to be packed into a green net with attached Tesco wineglass label.

Appendix 2: Manuals forms used in the quality system

2.1 Paper form used for the control in "Goods In"

SH PRATTS BANANAS

14-6c

Green Reports: CEIBO
Vessel: Dominica.
Container: Roseau.

Trays
Large
Small 1386

Load N°: 1|0408
Week: 7.
Date: 19-2-01

PLANTATION	2282	2282	3280	3280	2284
PACKER	1592	1546	1610	1624	1490
PRESENTATION					
HIGH PACKING	ok	ok	ok	ok	ok
HANDS FIT TOGETHER	ok	ok	ok	ok	ok
HOMOGENEITY SIZE TOP LAYER	ok	ok	ok	ok	ok
HOMOGENEITY GRADE	1	1	1	1	1
POSITION PLASTIC AND PAD	1	1	1	1	1
TOTAL					
DEFECTS PER FINGERS					
NUMBER OF FINGERS	109	101	114	99	94
PACKING RUBBING					
PACKING SHOCKS	3	5	5	3	4
BRUISING		2			
NECK CREASING					
HANDLING DEFECTS					
PLANTATION SCRATCHES	5	7	6	6	5
MATURITY STAIN					
KNIFE CUT	1			1	1
HEAVY INFILTRATION					
SPECKLE					
FLOWER			2	1	2
DRY LATEX	4	5	3	4	3
GELATINOUS LATEX	2	3	2	3	3
CHANCRE				2	2
CROWN ROT					
NECK STRESS					
TOTAL					
FINAL SCORE					

COMMENTS: 23cm.
Shocks, Scarring, latex, chancre,
75% ok for Supermkt

2.2 Forms used for the control in ripening rooms

ROOM TEMP 14°			Banana Ripening Assessment Sheet																	
DATE 20-08-01			Production date: 21-08-01					CLIENT: TESCO												
ROOM: 30			Pack size 15KG					Quality										Scoring		
ID	Brand	pull and cut (yes/no)	Plant	Colour stage	Pulp temp	Pods	Size Range	Chill	Rot	Inf	SCR	Grade	DL	GL	BRU	NC	NS	Quality	Colour	Size
1-20561	CIRICA	Yes	28	2½-3	15.1	4-7	22-25		P					✓				1	A	A
2			27	2½-3	17.0	4-7	20-24				✓			✓✓				1	A	A
3				2½-3	15.4	4-8	21-25				✓			✓	✓			1	A	A
4				2½-3	15.2	5-7	22-25						✓		✓		✓	1	A	A
5			28	2½-3	16.0	5-8	20-24				✓			✓				1	A	A
DATE																				
1-2058	CIRKA	Yes	27	2½-3	15.6	4-8	19-24				✓			✓✓				1	A	A
2			25	2½	15.5	5-7	21-23				✓		✓					1	A	A
3			27	2½-3	16.1	5-7	21-25				✓✓				✓			1	A	A
4			28	2½	15.0	4-7	22-25						✓	✓				1	A	A
5				2½-3	15.8	4-8	23-24		P					✓	✓			1	A	A

Overall comments: FOUND SOME LIGHT, MED LATEX + SOME PEEL ROT.

1: Overall clean but odd medium defects/pass			Supervisor informed YES/NO			
2: Overall clean but odd medium and heavy defects/pass			Size spec	TESCO	WAITROSE	MORISSON
3: Overall clean but some medium and heavy defects/marginal			Smalls	14-19cm	and 10% 22 - 23	14-20 cm
4: Overall marked fruits/failed			Large	19-25cm	24-27max 10% 23-24	19 - 25 cm
Colour	Size	C: Crown Rot, N: Neck Rot, P: Peel Rot	Medium		19 - 23 cm	
A: Accepted colour	A: Good size	NC/CS: Neck creasing/Neck stress	Baby		8 - 11 cm	14-18 cm
B: Too colour	B: Too small	INF: Infiltrations	Value	14-25cm		14 - 25 cm
C: Too Green	C: Too large	BRU: Bruising	EM & KM	14-19cm		
D: Mixed	D: Mixed	SCR: Scarring	Organic	17 min	14-19 cm	

This document assesses the bananas daily two days before being sent to the production chain.

The quality controllers have to fill the fields regarding the clients' specifications as written at the bottom of the document. The assessment of the defects is done by adding up to four ticks (none, light, medium and heavy).

2.3 Forms used for the control in Production

This stage checks the bananas according to the clients' specifications; consequently the quality control requires several different forms.

Here are examples of the three form categories currently utilised. Each one is categorised according to the client and the type of fruit.

COSTCO MAGNA PARK

COMPLETED BY........................... DATE .... I.D........................

ORIGIN .... BRAND .... PLAN ....

	PLAN	COLOUR	WEIGHT	TEMP		TOTAL HANDS	CHILL	ROT	SC	LATEX	BRUISING	NECK INJURY	OTHER	& DEFECTS	
1															
2															
3															
4															
5															

APPEARANCE
TO BE FREE FROM BREAKDOWN MOULD, BRUISING, CROWN/NECK ROT DAMAGED FRUIT INCLUDING HEALED CUTS SKIN DISCOLOURATION, SOILING, HEAVY LATEX, HEAVY SCARING, PEEL ROT.

SKIN DEFECTS SUCH AS SPECKLE, THRIP AND LIGHT LATEX STAINING ARE ACCEPTABLE SO LONG AS THEY ARE LIGHT AND DO NOT DETRACT FROM THE OVERALL APPEARANCE OF THE FRUIT.

COLOURATION = 2
LIGHT ✓ MEDUIM ✓✓ HEAVY ✓✓✓
COMENTS

ORGANIC WAITROSE DOC ORG 4

Completed by: ____________ **Date:** ____________ **D/U:** ____________ **ID:** ____________

Origin: ____________ **Brand:** ____________ **Plant:** ____________

Plan	Col.	Weight	Temp	Size	Pod	Total Hand	Rot	SC	DL	GL	BR	NI	Other	% Defects

Chill	Trace	Medium	Heavy	None

Specification:
Count: 18 x 5 Quality: 20% max defects Colour 3-3.5

Comments

In the following documents dedicated to Tesco, one contains hand written additions. These are the improvements required for the new system.

The first form does a control by boxes and provides a percentage of compliance (colour, size, and temperature). The second is done on fifty hands that assess the defects by finger (each banana of the hand).

This control is obviously more accurate but involves lots of additional work.

Using handheld computers could save some time on the fruits' assessment and therefore applied the control by hand to the whole process of the quality control.

TESCO VARIABLES

DOC 120/1A

DATE I.D NUMBER PLANT
Q.A ORIGIN DEPOT

SPECIFIC SAMPLE ATTRIBUTES

BANANA COLOUR

	NON	NON	PART	FULL	NON
CASE	B	C	CD	D	E
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

% COL COMPLIANCE

FULL	
PART	
NON	

UPD Under Peel Discolouration

	FULL	PART	NON
	NO/LI	MED	HEAVY
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

% UPD COMPLIANCE

FULL	
PART	
NON	

Weight Sample

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
aver	
%	

TEMPERATURE SAMPLE

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
AVE	
%COM	

1 FRUIT = 10%

SIZE SAMPLE

2 fields: Min Max

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
AVE		
%COM		

Compliance

P.R.S LABEL

YES	NO

COMMENTS

	LEVEL C DEFECTS							LEVEL B DEFECTS							
HAND	PLR	CRO	NKR	NKI	BRU	LAT	SCA	CRO	NKR	NKI	BRU	LAT	SCR	TOT DEF	ADF
1															
2															
3															
4															
5															
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COMMENTS

Appendix 3: Anova Tables for Experimental part 1

Table 0.1: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	201.865	201.865	65.8	<0.001
Residual	68	208.608	3.068		
Total	69	410.473			

Table 0.2: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	101.6	101.160	14.36	<0.001
Residual	68	479.128	7.046		
Total	69	580.289			

Table 0.3: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	1.459	1.459	0.52	0.489
Residual	8	22.244	2.78		
Total	9	23.703			

Table 0.4: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	17.213	17.213	3.56	0.096
Residual	8	38.657	4.832		
Total	9	55.870			

Table 0.5: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.986	0.986	0.64	0.446
Residual	8	12.261	1.533		
Total	9	13.247			

Table 0.6: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	2.256	2.256	0.56	0.474
Residual	8	32.002	1.000		
Total	9	34.258			

Table 0.7: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.09	0.09	0.00	0.957
Residual	8	227.55	28.44		
Total	9	227.64			

Table 0.8: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	5.85	5.85	0.40	0.542
Residual	8	115.69	14.46		
Total	9	121.54			

Table 0.9: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	62.75	62.75	3.21	0.111
Residual	8	156.57	19.57		
Total	9	219.33			

Table 0.10: Hue Angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.2342	0.2342	0.53	0.488
Residual	8	3.5395	0.4424		
Total	9	3.7737			

Table 0.11: Hue Angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	33.455	33.455	9.77	0.014
Residual	8	27.394	3.424		
Total	9	60.849			

Table 0.12: Hue Angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.480	0.4890	0.54	0.482
Residual	8	7.1894	0.8987		
Total	9	7.6784			

Table 0.13: Hue Angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.5312	0.5312	0.86	0.382
Residual	8	4.9598	0.6200		
Total	9	5.4910			

Table 0.14: Hue Angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.691	0.691	0.12	0.737
Residual	8	45.510	5.689		
Total	9				

Table 0.15: Hue Angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.094	0.094	0.03	0.878
Residual	8	30.038	3.755		
Total	9	30.132			

Table 0.16: Hue Angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	1.805	1.805	0.69	0.431
Residual	8	21.043	2.630		
Total	9	22.848			

Table 0.17: Relative fresh weight √ day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.02077	0.02077	1.65	0.235
Residual	8	0.1093	0.01262		
Total	9	0.12170			

Table 0.18: Relative fresh weight √ day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.02563	0.02563	1.01	0.344
Residual	8	0.20294	0.02537		
Total	9	0.22858			

Table 0.19: Relative fresh weight √ day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.09053	0.09053	7.86	0.023
Residual	8	0.09212	0.01152		
Total	9	0.18265			

Table 0.20: Relative fresh weight √ day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.04183	0.04183	0.46	0.516
Residual	8	0.72377	0.09047		
Total	9	0.76560			

Table 0.21: Relative fresh weight √ day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.01099	0.01099	0.33	0.579
Residual	8	0.26335	0.03292		
Total	9	0.27433			

Table 0.22: Relative fresh weight √ day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum	1	0.20568	0.20568	8.52	0.019
Residual	8	0.19304	0.02413		
Total	9	0.39872			

Table 0.23: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.003203	0.003203	0.38	0.553
Residual	8	0.066827	0.008353	1.44	
Banana.Type.Position st.					
Position	2	0.015727	0.007863	1.35	0.287
Type.Position	2	0.026447	0.013223	2.27	0.135
Residual	16	0.093093	0.005818		
Total	29	0.205297			

Table 0.24: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.034680	0.034680	4.90	0.058
Residual	8	0.056587	0.007073	3.08	
Banana.Type.Position st.					
Position	2	0.002987	0.001493	0.65	0.535
Type.Position	2	0.009920	0.004960	2.16	0.147
Residual	16	0.036693			
Total	29	0.140867			

Table 0.25: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0070533	0.0070533	3.74	0.089
Residual	8	0.0150933	0.0018867	1.97	
Banana.Type.Position st.					
Position	2	0.0013067	0.0006533	0.68	0.519
Type.Position	2	0.0033867	0.0016933	1.77	0.202
Residual	16	0.0153067	0.0009567		
Total	29	0.0421467			

Table 0.26: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0034133	0.0034133	1.72	0.226
Residual	8	0.0158400	0.0019800	3.42	
Banana.Type.Position st.					
Position	2	0.0016800	0.0008400	1.47	0.259
Type.Position	2	0.0006667	0.0003333	0.58	0.569
Residual	16	0.0091200	0.0005700		
Total	29	0.0307200			

Table 0.27: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0000133	0.0000133	0.01	0.915
Residual	8	0.0088000	0.0011000	1.80	
Banana.Type.Position st.					
Position	2	0.0006667	0.0003333	0.55	0.589
Type.Position	2	0.0005067	0.0002533	0.42	0.667
Residual	16	0.0097600	0.0006100		
Total	29	0.0197467			

Table 0.28: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.000213	0.000213	0.12	0.737
Residual	8	0.014133	0.001767	1.16	
Banana.Type.Position st.					
Position	2	0.011760	0.005880	3.85	0.043
Type.Position	2	0.000347	0.000173	0.11	0.893
Residual	16	0.024427			
Total	29	0.050880			

Table 0.29: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.000853	0.000853	0.35	0.572
Residual	8	0.019627	0.002453	1.85	
Banana.Type.Position st.					
Position	2	0.009627	0.004813	3.64	0.050
Type.Position	2	0.004667	0.002333	1.76	0.203
Residual	16	0.021173	0.001323		
Total	29				

Table 0.30: Starch content day 2 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	52.5079	52.5079	4.28	0.072
Residual	8	98.1939	12.2742	28.63	
Banana.Type.Position st.					
Position	2	6.0977	3.0488	7.11	0.006
Type.Position	2	6.0977	3.0488	7.11	
Residual	16	6.8599	0.4287		
Total	29	169.7570			

Table 0.31: Starch content day 4 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	62.031	62.031	2.03	0.192
Residual	8	244.949	30.619	6.22	
Banana.Type.Position st.					
Position	2	120.646	60.323	12.25	<0.001
Type.Position	2	16.280	8.140	1.65	0.223
Residual	16	78.794	4.925		
Total	29	522.701			

Table 0.32: Starch content day 6 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	109.880	109.880	10.08	0.013
Residual	8	87.222	10.903	2.24	
Banana.Type.Position st.					
Position	2	46.280	23.140	4.76	0.024
Type.Position	2	35.581	17.791	3.66	0.049
Residual	16	77.737			

Total	29	356.701			

Table 0.33: Starch content day 8 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.82	0.82	0.03	0.871
Residual	8	234.71	29.34	2.40	
Banana.Type.Position st.					
Position	2	130.34	65.17	5.32	0.017
Type.Position	2	34.05	17.03	1.39	0.277
Residual	16	195.91	12.24		
Total	29	595.84			

Table 0.34: Starch content day 10 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	191.75	191.75	1.49	0.257
Residual	8	1031.31	128.91	7.01	
Banana.type.pos. st.					
Position	2	253.98	126.99	6.90	0.007
Type.Position	2	45.99	23	1.25	0.313
Residual	16	294.39			
Total	29	1817.43			

Table 0.35: Starch content day 12 (Angular transformation)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	3.9	3.9	0.01	0.928
Residual	8	3611.1	451.4	3.99	
Banana.Type.Position st.					
Position	2	678.3	339.2	3.00	0.078
Type.Position	2	131.2	65.2	0.58	0.571
Residual	16	1808.9	113.1		
Total	29	6233.5			

Table 0.36: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0653	0.0653	0.01	0.909
Residual	8	37.2717	4.6590	1.69	
Banana. Position st.					
Position	2	19.8080	9.9040	3.60	0.051
Type.Position	2	2.5527	1.2763	0.46	0.637
Residual	16	44.0193	2.7512	1.10	
Banana.Pos.Method. st.					
Method	1	830.0280	830.0280	332.26	<0.001
Position.Method	2	15.9920	7.9960	3.20	0.059
Method.Type	1	19.8453	19.8453	7.94	0.010
Position.Method.Type	2	1.9247	0.9623	0.39	0.684
Residual	14	59.9550	2.4981	2.53	
Ban.Pos.Meth.Device. st					
Device	1	4.8000	4.8000	4.86	0.032
Position.Device	2	0.0140	0.0070	0.01	0.993
Method.Device	1	14.7000	14.7000	14.89	<0.001
Type.Device	1	3.8880	3.8880	3.94	0.053

Position.Method.Device	2	0.7220	0.3610	0.37	0.696
Position.Type.Device	2	5.3420	2.6710	2.70	0.077
Method.Type.Device	1	0.3000	0.3000	0.30	0.584
Pos.Meth.Type.Device	2	4.0460	2.0230	2.05	0.140
Residual	48	47.3980	0.9875		
Total	119	1112.6720			

Table 0.37: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	5.084	5.084	1.15	0.315
Residual	8	35.456	4.432	1.18	
Banana. Position st.					
Position	2	17.801	8.900	2.38	0.125
Type.Position	2	3.603	1.801	0.48	0.626
Residual	16	59.850	3.741	0.87	
Banana.Pos.Method. st.					
Method	1	1460.914	1460.194	341.37	<0.001
Position.Method	2	5.525	2.762	0.65	0.533
Method.Type	1	15.194	15.194	3.55	0.072
Position.Method.Type	2	21.075	10.537	2.46	0.107
Residual	14	102.710	4.280	1.50	
Ban.Pos.Meth.Device. st					
Device	1	6.302	6.302	2.21	0.144
Position.Device	2	0.181	0.090	0.03	0.969
Method.Device	1	156.180	156.180	54.69	<0.001
Type.Device	1	11.844	11.844	4.15	0.047
Position.Method.Device	2	0.225	0.112	0.04	0.961
Position.Type.Device	2	1.405	0.702	0.25	0.783
Method.Type.Device	1	0.494	0.494	0.17	0.679
Pos.Meth.Type.Device	2	0.725	0.362	0.13	0.881
Residual	48	137.080	2.856		
Total	119	2041.646			

Table 0.38: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.048	0.048	0.01	0.918
Residual	8	33.729	4.216	6.32	
Banana. Position st.					
Position	2	6.047	3.024	4.54	0.028
Type.Position	2	3.179	1.589	2.38	0.124
Residual	16	10.666	0.667	0.58	
Banana.Pos.Method. st.					
Method	1	203.320	203.320	175.38	<0.001
Position.Method	2	1.785	0.893	0.77	0.474
Method.Type	1	1.200	1.200	1.04	0.319
Position.Method.Type	2	0.316	0.158	0.14	0.873
Residual	14	27.823	1.159	1.06	
Ban.Pos.Meth.Device. st					
Device	1	89.096	89.096	81.28	<0.001
Position.Device	2	0.741	0.371	0.34	0.715
Method.Device	1	45.880	45.880	41.85	<0.001
Type.Device	1	0.000	0.000	0.00	1.000
Position.Method.Device	2	0.535	0.268	0.24	0.784
Position.Type.Device	2	2.154	1.077	0.98	0.382
Method.Type.Device	1	1.728	1.728	1.58	0.215
Pos.Meth.Type.Device	2	4.117	2.058	1.88	0.164

Residual	48	52.618	1.096		
Total	119	484.984			

Table 0.39: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.1763	0.1763	0.04	0.843
Residual	8	33.51217	4.1902	5.65	
Banana. Position st.					
Position	2	5.8662	2.9331	3.96	0.040
Type.Position	2	1.9422	0.9711	1.31	0.297
Residual	16	11.8633	0.7415	0.54	
Banana.Pos.Method. st.					
Method	1	59.0803	59.0803	43.42	<0.001
Position.Method	2	16.1222	8.0611	5.92	0.008
Method.Type	1	0.8003	0.8003	0.59	0.451
Position.Method.Type	2	0.7542	0.3771	0.28	0.760
Residual	14	32.6530	1.3605	2.36	
Ban.Pos.Meth.Device. st					
Device	1	54.9453	54.9453	95.16	<0.001
Position.Device	2	0.7972	0.3986	0.69	0.506
Method.Device	1	30.4013	30.4013	52.65	<0.001
Type.Device	1	0.0653	0.0653	0.11	0.738
Position.Method.Device	2	2.5652	1.2826	2.22	0.119
Position.Type.Device	2	0.5612	0.2806	0.49	0.618
Method.Type.Device	1	1.1213	1.1213	1.94	0.170
Pos.Meth.Type.Device	2	2.8292	1.1446	2.45	0.097
Residual	48	27.7140	0.5774		
Total	119	283.7797			

Table 0.40: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	6.3480	6.3480	1.12	0.321
Residual	8	45.433	5.6792	4.88	
Banana. Position st.					
Position	2	7.0685	3.5343	3.04	0.076
Type.Position	2	1.3715	0.6858	0.59	0.567
Residual	16	18.6317	1.1645	1.31	
Banana.Pos.Method. st.					
Method	1	33.0750	33.0750	37.29	<0.001
Position.Method	2	0.4625	0.2312	0.26	0.773
Method.Type	1	0.1920	0.1920	0.22	0.646
Position.Method.Type	2	2.0855	1.0427	1.18	0.326
Residual	14	21.2850	0.8860	1.72	
Ban.Pos.Meth.Device. st					
Device	1	97.5630	97.5630	188.78	<0.001
Position.Device	2	0.3972	0.1986	0.38	0.683
Method.Device	1	33.4963	33.4963	64.82	<0.001
Type.Device	1	0.6483	0.6453	1.25	0.269
Position.Method.Device	2	1.3352	0.6676	1.29	0.284
Position.Type.Device	2	1.1562	0.5781	1.12	0.335
Method.Type.Device	1	0.8333	0.8333	1.61	0.210
Pos.Meth.Type.Device	2	0.4702	0.2351	0.45	0.637
Residual	48	24.8060	0.5168		
Total	119	296.6530			

Table 0.41: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	3.8163	3.8163	0.59	0.465
Residual	8	51.9323	6.4915	7.74	
Banana. Position st.					
Position	2	2.5522	1.2761	1.52	0.249
Type.Position	2	2.1622	1.0811	1.29	0.303
Residual	16	13.4257	0.8391	0.84	
Banana.Pos.Method. st.					
Method	1	0.8003	0.8003	0.80	0.379
Position.Method	2	4.2682	2.1341	2.14	0.139
Method.Type	1	0.0563	0.0563	0.06	0.814
Position.Method.Type	2	3.5102	1.7551	1.76	0.193
Residual	14	23.9100	0.9962	3.74	
Ban.Pos.Meth.Device. st					
Device	1	16.4280	16.4280	61.64	<0.001
Position.Device	2	0.2205	0.1103	0.41	0.664
Method.Device	1	74.8920	74.8920	281.02	<0.001
Type.Device	1	0.9720	0.9720	3.65	0.062
Position.Method.Device	2	0.3885	0.1943	0.73	0.488
Position.Type.Device	2	0.9105	0.4552	1.71	0.192
Method.Type.Device	1	0.3000	0.3000	1.13	0.294
Pos.Meth.Type.Device	2	0.1665	0.0833	0.31	0.733
Residual	48	12.7920	0.2665		
Total	119	213.5037			

Table 0.42: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	6.075	6.075	0.61	0.456
Residual	8	79.3135	9.9144	21.24	
Banana. Position st.					
Position	2	8.3312	4.1656	8.92	0.002
Type.Position	2	11.2385	5.6193	12.04	<0.001
Residual	16	7.4687	0.4668	0.72	
Banana.Pos.Method. st.					
Method	1	71.3763	71.3763	72.83	<0.001
Position.Method	2	9.0852	4.5426	6.98	0.004
Method.Type	1	22.707	22.707	34.91	<0.001
Position.Method.Type	2	6.3245	3.1623	4.86	0.017
Residual	14	15.6120	0.6505	1.73	
Ban.Pos.Meth.Device. st					
Device	1	0.6453	0.6453	1.72	0.197
Position.Device	2	10.3292	5.1646	13.73	<0.001
Method.Device	1	76.1613	76.1613	202.42	<0.001
Type.Device	1	41.7720	41.7720	111.02	<0.001
Position.Method.Device	2	6.6632	3.3316	8.85	<0.001
Position.Type.Device	2	4.8965	2.4483	6.51	0.003
Method.Type.Device	1	32.4480	32.4480	86.24	<0.001
Pos.Meth.Type.Device	2	6.1145	3.0573	8.13	<0.001
Residual	48	18.0600	0.3762		
Total	119	410.6237			

Appendix 4: Anova tables for experimental part 2

Appendix 4.1: Anova Tables for harvest A

Table 0.1: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	338.965	338.965	85.51	<0.001
Residual	278	1101.992	3.964		
Total	279	1440.957			

Table 0.2: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	100.856	100.856	54.64	<0.001
Residual	278	513.126	1.846		
Total	279	613.982			

Table 0.3: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	38.750	38.750	6.52	0.015
Residual	38	225.771	5.941		
Total	39	264.521			

Table 0.4: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	27.506	27.506	5.04	0.031
Residual	38	207.446	5.549		
Total	39	234.952			

Table 0.5: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	12.499	12.499	4.68	0.037
Residual	38	101.396	2.668		
Total	39	113.895			

Table 0.6: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	10.795	10.795	9.13	0.004
Residual	38	44.921	1.182		
Total	39	55.716			

Table 0.7: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	65.536	65.536	12.04	0.001
Residual	38	206.895	5.445		
Total	39	272.431			

Table 0.8: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	51.348	51.348	5.71	0.022
Residual	38	541.836	8.996		
Total	39	393.184			

Table 0.9: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	254.924	254.924	38.07	<0.001
Residual	38	254.432	6.696		
Total	39	509.356			

Table 0.10: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	3.9621	3.9621	4.19	0.048
Residual	38	35.9481	0.9460		
Total	39	39.9102			

Table 0.11: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.262	2.262	1.09	0.303
Residual	38	78.909	2.077		
Total	39	81.070			

Table 0.12: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.018	0.018	0.00	0.950
Residual	38	167.820	4.416		
Total	39	167.837			

Table 0.13: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	7.5327	7.5327	16.81	<0.001
Residual	38	17.0258	0.4480		
Total	39	24.5585			

Table 0.14: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	27.319	27.319	27.22	<0.001
Residual	38	38.141	1.004		
Total	39	65.460			

Table 0.15: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	653.6	653.6	0.83	0.369
Residual	38	30058.2	791.0		
Total	39	30711.8			

Table 0.16: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	41.322	41.322	32.16	<0.001
Residual	38	48.829	1.285		
Total	39	90.151			

Table 0.17: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.34022	0.34022	20.74	<0.001
Residual	38	0.62346	0.01641		
Total	39	0.96368			

Table 0.18: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.02134	0.02134	0.88	0.354
Residual	38	0.91988	0.91988		
Total	39	0.94123	0.94123		

Table 0.19: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.00217	0.00217	0.05	0.829
Residual	38	1.73110	0.04556		
Total	39	1.73327			

Table 0.20: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001	0.0011	0.01	0.921
Residual	38	4.2547	0.1120		
Total	39	4.2558			

Table 0.21: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.08284	0.08284	1.45	0.235
Residual	38	2.16623	0.5701		
Total	39	2.24908			

Table 0.22: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.24518	0.24518	3.43	0.072
Residual	38	2.71671	0.07149		
Total	39	2.96189			

Table 0.23: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.1125	2.1125	1.22	0.277
Residual	38	65.9670	1.7360	2.32	
Ban.Type.meth. st.					
Method	1	1463.7605	1463.7605	1953.94	<0.001
Type.Method	1	10.5125	10.5125	14.03	<0.001
Residual	38	28.4670	0.7491		

Total	79	1570.8195

Table 0.24: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	82.825	82.825	18.89	<0.001
Residual	38	166.591	4.384	1.76	
Ban.Type.meth st.					
Method	1	989.824	989.824	398.15	<0.001
Type.Method	1	38.364	38.364	15.43	<0.001
Residual	38	94.471	2.486		
Total	79	1372.075			

Table 0.25: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	59.5125	59.5125	35.14	<0.001
Residual	38	64.3550	1.6936	3.04	
Ban.Type.meth st.					
Method	1	427.8125	427.8125	768.46	<0.001
Type.Method	1	2.8125	2.8125	5.05	0.030
Residual	38	21.1550	0.5567		
Total	79	575.6475			

Table 0.26: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	37.5380	37.5380	52.44	<0.001
Residual	38	27.2040	0.7159	1.82	
Ban.Type.meth st.					
Method	1	254.8980	254.8980	647.30	<0.001
Type.Method	1	0.0980	0.0980	0.25	0.621
Residual	38	14.9640	0.3938		
Total	79	334.7020			

Table 0.27: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	5.9951	5.9951	4.15	0.049
Residual	38	54.8918	1.4445	4.26	
Ban.Type.meth st.					
Method	1	109.2781	109.2781	322.11	<0.001
Type.Method	1	0.5951	0.5951	1.75	0.193
Residual	38	12.8917	0.3393		
Total	79	183.6519			

Table 0.28: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	7.2000	7.2000	6.15	0.018
Residual	38	44.5180	1.1715	3.02	
Ban.Type.meth st.					
Method	1	87.3620	87.3620	224.95	<0.001
Type.Method	1	7.2000	7.2000	18.54	<0.001

Residual	38	14.7580	0.3884		
Total	79	161.0380			

Table 0.29: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0980	0.0980	0.08	0.776
Residual	38	45.2840	1.1917	3.01	
Ban.Type.meth st.					
Method	1	128.0180	128.0180	323.36	<0.001
Type.Method	1	0.3380	0.3380	0.85	0.361
Residual	38	15.0440	0.3959		
Total	79	188.7820			

Table 0.30: Titratable acidity day 0 (not measured for conventional)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	0				
Residual	19	0.129120	0.006796		
Total	19	0.129120			

Table 0.31: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.030802	0.030802	11.91	0.001
Residual	38	0.098275	0.002586		
Total	39	0.129077			

Table 0.32: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.068890	0.068890	12.41	0.001
Residual	38	0.211020	0.005553		
Total	39	0.279910			

Table 0.33: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.005760	0.005760	1.38	0.248
Residual	38	0.158840	0.004180		
Total	39	0.164600			

Table 0.34: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.049702	0.049702	5.23	0.028
Residual	38	0.361295	0.009508		
Total	39	0.410997			

Table 0.35: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000360	0.000360	0.32	0.577
Residual	38	0.043280	0.001139		
Total	39	0.043640			

Table 0.36: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.005760	0.005760	3.44	0.071
Residual	38	0.063640	0.001675		
Total	39	0.069400			

Table 0.37: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	69.17	69.17	2.32	0.136
Residual	38	1134.72	29.86		
Total	39	1203.89			

Table 0.38: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	23.104	23.014	2.64	0.112
Residual	38	332.567	8.752		
Total	39	355.671			

Table 0.39: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.04225	0.04225	0.97	0.330
Residual	38	1.64750	0.04336		
Total	39	1.68975			

Table 0.40: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.04225	0.04225	0.50	0.485
Residual	38	3.22150	0.08478		
Total	39	3.26375			

Table 0.41: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.7840	0.7840	3.80	0.059
Residual	38	7.8320	0.2061		
Total	39	8.6160			

Table 0.42: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.32400	0.32400	5.10	0.030
Residual	38	2.41600	0.06358		
Total	39	2.74000			

Table 0.43: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.9160	2.9160	23.94	<0.001
Residual	38	4.6280	0.1218		
Total	39	7.5440			

Table 0.44: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0258	0.0258	0.06	0.807
Residual	38	16.1794	0.4258		
Total	39	16.2052			

Table 0.45: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	811.48	811.48	22.79	<.001
Residual	38	1352.88	35.60		
Total	39	2164.36			

Table 0.46: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	151.17	151.17	2.85	0.099
Residual	38	2012.18	53.95		
Total	39	2163.36			

Table 0.47: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	174.59	174.59	5.26	0.027
Residual	38	1261.78	33.20		
Total	39	1436.37			

Table 0.48: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	115.86	115.86	5.45	0.025
Residual	38	807.78	21.26		
Total	39	923.64			

Table 0.49: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	4891.1	4891.1	47.11	<.001
Residual	38	3945.7	103.8		
Total	39	8836.8			

Appendix 4.2: Anova Tables for harvest B

Table 0.46: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	7.498	7.498	3.46	0.064
Residual	278	602.350	2.167		
Total	279	609.848			

Table 0.47: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	6.047	6.047	3.04	0.082
Residual	278	552.948	1.989		
Total	279	558.995			

Table 0.48: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	42.29	42.29	2.59	0.116
Residual	38	621.51	16.36		
Total	39	663.80			

Table 0.49: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.042	0.042	0.01	0.910
Residual	38	123.013	3.237		
Total	39	123.054			

Table 0.50: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.278	1.278	1.00	0.324
Residual	38	48.700	1.282		
Total	39	49.97			

Table 0.51: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	12.566	12.566	6.34	0.016
Residual	38	75.269	1.981		
Total	39	87.836			

Tble 0.52: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.176	0.176	0.02	0.875
Residual	38	268.128	7.056		
Total	39	268.304			

Table 0.53: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnana stratum	1	23.23	23.23	2.28	0.140
Residual	38	387.93	10.21		
Total	39	411.15			

Table 0.54: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	82.97	82.97	5.60	0.023
Residual	38	563.45	14.83		
Total	39	646.42			

Table 0.55: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.5531	1.5531	2.71	0.108
Residual	38	21.7545	0.5725		
Total	39	23.3076			

Table 0.56: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.7271	1.7271	2.96	0.093
Residual	38	22.1351	0.5825		
Total	39	23.8621			

Table 0.57: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0111	0.0111	0.01	0.911
Residual	38	33.0995	0.8710		
Total	39	33.1106			

Table 0.58: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.9155	0.9155	2.13	0.153
Residual	38	16.3429	0.4301		
Total	39	17.2584			

Table 0.59: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	868.3	868.3	1.11	0.298
Residual	38	29674.3	780.9		
Total	39	30542.6			

Table 0.60: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	742	742	0.91	0.346
Residual	38	30950.0	814.5		
Total	39	31691.9			

Table 0.61: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.510	1.510	0.38	0.544
Residual	38	152.687	4.018		
Total	39	154.196			

Table 0.62: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

Type	1	0.07635	0.07635	4.32	0.044
Residual	38	0.67165	0.01768		
Total	39	0.74800			

Table 0.63: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.09921	0.09921	2.80	0.103
Residual	38	1.34	0.03547		
Total	39	1.44715			

Table 0.64: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.29827	0.29827	12.05	0.001
Residual	38	0.94075	0.02476		
Total	39	1.23903			

Table 0.65: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.45066	0.45066	9.84	0.003
Residual	38	1.74015	0.04579		
Total	39	2.19080			

Table 0.66: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.15551	0.15551	4.41	0.042
Residual	38	1.33977	0.03526		
Total	39	1.49528			

Table 0.67: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0168	0.0168	0.05	0.828
Residual	38	13.4136	0.3530		
Total	39	13.4305			

Table 0.68: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	0.3125	0.3125	0.32	0.575
Type	38	37.1750	0.98783	1.00	
Ban.type.meth. st					
Method	1	1852.8125	1852.8125	1893.93	<0.001
Type.Method	1	0.3125	0.3125	0.32	0.575
Residual	38	37.1750	0.9783		
Total	79	1927.7875			

Table 0.69: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	5.940	5.940	1.74	0.196
Type	38	130.079	3.423	2.48	
Ban.type.meth. st					
Method	1	639.581	639.581	463.47	<0.001
Type.Method	1	7.320	7.320	5.30	0.027
Residual	38	52.439	1.380		

Total	79	835.360

Table 0.70: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	0.5120	0.5120	0.45	0.505
Type	38	42.8560	1.1278	7.27	
Ban.type.meth. st					
Method	1	172.8720	172.8720	1114.17	<0.001
Type.Method	1	0.0320	0.0320	0.21	0.652
Residual	38	5.8960	0.1552		
Total	79	222.1680			

Table 0.71: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	0.8405	0.8405	0.77	0.386
Type	38	41.4470	1.0907	2.97	
Ban.type.meth. st					
Method	1	59.5125	59.5125	161.92	<0.001
Type.Method	1	0.4205	0.4205	1.14	0.292
Residual	38	13.9670	0.3676		
Total	79	116.1875			

Table 0.72: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	1.9220	1.9220	2.91	0.096
Type	38	25.0680	0.6597	0.90	
Ban.type.meth. st					
Method	1	26.4500	26.4500	35.96	<0.001
Type.Method	1	0.2420	0.2420	0.33	0.570
Residual	38	27.9480	0.7355		
Total	79	81.6300			

Table 0.73: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	0.4805	0.4805	0.25	0.618
Type	38	72.2615	1.9016	2.13	
Ban.type.meth. st					
Method	1	10.6580	10.6580	11.96	0.001
Type.Method	1	0.0125	0.0125	0.01	0.906
Residual	38	33.8495			
Total	79	117.2620			

Table 0.74: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Bnanana stratum	1	22.155	22.155	5.95	0.020
Type	38	141.512	3.724	1.51	
Ban.type.meth. st					
Method	1	113.050	113.050	45.77	<0.001
Type.Method	1	30.135	30.135	12.20	0.001
Residual	38	93.860	2.470		

Total	79	400.712

Table 0.75: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.007840	0.007842	6.90	0.012
Residual	38	0.043160	0.001136		
Total	39	0.051000			

Table 0.76: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.035402	0.035402	4.42	0.042
Residual	38	0.304635	0.008017		
Total	39	0.340037			

Table 0.77: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.010890	0.010890	1.23	0.275
Residual	38	0.116300	0.003061		
Total	39	0.127190			

Table 0.78: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.019360	0.019360	7.32	0.010
Residual	38	0.100440	0.002643		
Total	39	0.119800			

Table 0.79: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001000	0.001000	0.20	0.661
Residual	38	0.194040	0.005106		
Total	39	0.195040			

Table 0.80: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000040	0.000040	0.02	0.885
Residual	38	0.071960	0.001894		
Total	39	0.072000			

Table 0.81: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001210	0.001210	0.48	0.491
Residual	38	0.094940	0.002498		
Total	39	0.096150			

Table 0.82: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	17.82	17.82	0.83	0.367
Residual	38	814.00	21.42		
Total	39	831.82			

Table 0.83: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	27.33	27.23	1.84	0.184
Residual	38	563.75	14.84		
Total	39	590.97			

Table 0.84: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.55225	0.55225	6.84	0.013
Residual	38	3.06750	0.08072		
Total	39	3.61975			

Table 0.85: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.09025	0.09025	1.96	0.170
Residual	38	1.75350	0.04614		
Total	39	1.84375			

Table 0.86: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.06400	0.06400	1.03	0.316
Residual	38	2.35200	0.06189		
Total	39	2.41600			

Table 0.87: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.15625	0.15625	1.88	0.178
Residual	38	3.15350	0.08299		
Total	39	3.30975			

Table 0.88: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.4000	0.4000	2.09	0.156
Residual	38	7.2640	0.1912		
Total	39	7.6640			

Table 0.89: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.2467	0.2467	0.83	0.367
Residual	38	11.2444	0.2959		
Total	39	11.4911			

Table 0.90: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.05	1.05	0.08	0.776
Residual	38	484.14	12.74		
Total	39	485.19			

Table 0.91: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.71	0.71	0.04	0.842
Residual	38	670.20	17.64		
Total	39	670.92			

Table 0.92: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	121.85	121.85	1.41	0.242
Residual	38	3274.26	86.16		
Total	39	3396.11			

Table 0.93: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	18.34	18.34	0.70	0.408
Residual	38	996.83	26.23		
Total	39	1015.17			

Table 0.94: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	50.185	50.185	5.40	0.026
Residual	38	352.896	9.287		
Total	39	403.081			

Appendix 4.3: Anova tables and sensory analysis for harvest C

Appendix 4.3.1 Anova tables for harvest C

Table 0.88: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	34.845	34.845	6.89	0.009
Residual	278	1405.047	5.054		
Total	279	1439.892			

Table 0.89: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.033	0.033	0.01	0.912
Residual	278	755.707	2.718		
Total	279	755.740			

Table 0.90: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.513	0.513	0.15	0.704
Residual	38	133.129	3.503		
Total	39	133.642			

Table 0.91: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.025	0.025	0.01	0.924
Residual	38	103.163	2.715		
Total	39	103.188			

Table 0.92: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.601	2.601	1.65	0.207
Residual	38	59.923	1.577		
Total	39	62.524			

Table 0.93: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	4.3824	4.3824	5.63	0.023
Residual	38	29.5776	0.7784		
Total	39	33.9600			

Table 0.94: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	43.181	43.181	4.96	0.032
Residual	38	330.623	8.701		
Total	39	373.804			

Table 0.95: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	70.119	70.119	9.36	0.004
Residual	38	284.811	7.495		

Total	39	354.930

Table 0.96: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	20.22	20.22	1.73	0.196
Residual	38	443.79	11.68		
Total	39	464.01			

Table 0.97: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0894	0.0894	0.26	0.610
Residual	38	12.8658	0.3386		
Total	39	12.9552			

Table 0.98: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.050	0.050	0.05	0.832
Residual	38	41.565	1.094		
Total	39	41.615			

Table 0.99: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.9247	1.9247	2.47	0.125
Residual	38	29.6470	0.7802		
Total	39	31.5718			

Table 0.100: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.3393	1.3393	5.62	0.023
Residual	38	9.0613	0.2385		
Total	39	10.4006			

Table 0.101: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	15.760	15.760	8.23	0.007
Residual	38	72.787	1.915		
Total	39	88.547			

Table 0.102: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	14.814	14.814	7.73	0.008
Residual	38	72.865	1.918		
Total	39	87.679			

Table 0.103: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	9.373	9.373	3.72	0.061
Residual	38	95.842	2.522		
Total	39	105.214			

Table 0.104: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.041004	0.041004	5.60	0.023
Residual	38	0.278127	0.007319		
Total	39	0.319131			

Table 0.105: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.06476	0.06476	3.64	0.064
Residual	38	0.67573	0.01778		
Total	39	0.74049			

Table 0.106: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.02247	0.02247	0.44	0.511
Residual	38	1.94022	0.05106		
Total	39	1.96270			

Table 0.107: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.3830	0.3830	3.58	0.066
Residual	38	4.0688	0.1071		
Total	39	4.4518			

Table 0.108: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.18839	0.18839	3.71	0.062
Residual	38	1.92829	0.05074		
Total	39	2.11668			

Table 0.109: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0509	0.0509	0.36	0.553
Residual	38	5.3952	0.1420		
Total	39	5.4461			

Table 0.110: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.000	0.000	0.00	0.988
Residual	38	83.719	2.203	0.98	
Ban.type.meth. st					
Method	1	780.000	780.000	347.57	<0.001
Type.Method	1	0.061	0.061	0.03	0.870
Residual	38	85.279	2.244		
Total	79	949.060			

Table 0.111: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	17.1125	17.1125	9.76	0.003

Residual	38	66.6270	1.7533	3.80	
Ban.type.meth. st					
Method	1	461.7605	461.7605	999.999	<0.001
Type.Method	1	2.1125	2.1125	4.57	0.039
Residual	38	17.5470	0.4618		
Total	79	565.1595			

Table 0.112: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	1.8000	1.8000	1.55	0.221
Residual	38	44.1180	1.1610	2.51	
Ban.type.meth. st					
Method	1	89.0420	89.0420	192.27	<0.001
Type.Method	1	0.0000	0.0000	0.00	1.000
Residual	38	17.5980	0.4631		
Total	79	152.5580			

Table 0.113: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.4500	0.4500	0.44	0.513
Residual	38	39.1820	1.0311	2.76	
Ban.type.meth. st					
Method	1	49.9280	49.9280	133.40	<0.001
Type.Method	1	0.4500	0.4500	1.20	0.280
Residual	38	14.2220	0.3743		
Total	79	104.2320			

Table 0.114: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.1780	2.1780	1.68	0.203
Residual	38	49.3340	1.2983	3.18	
Ban.type.meth. st					
Method	1	32.7680	32.7680	80.87	<0.001
Type.Method	1	0.0180	0.0180	0.04	0.835
Residual	38	15.4940	0.4077		
Total	79	99.7920			

Table 0.115: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.5205	2.5205	2.42	0.128
Residual	38	39.5950	1.0420	1.92	
Ban.type.meth. st					
Method	1	45.9045	45.9045	84.53	<0.001
Type.Method	1	0.0005	0.0005	0.00	0.976
Residual	38	20.6350	0.5430		
Total	79	108.6555			

Table 0.116: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					

Type	1	0.0405	0.0405	0.04	0.850
Residual	38	42.4790	1.1179	2.81	
Ban.type.meth. st					
Method	1	29.0405	29.0405	72.99	<0.001
Type.Method	1	0.2205	0.2205	0.55	0.461
Residual	38	15.1190	0.3979		
Total	79	86.8995			

Table 0.117: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000640	0.000640	0.27	0.606
Residual	38	0.089720	0.002361		
Total	39	0.090360			

Table 0.118: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.010890	0.010890	5.50	0.024
Residual	38	0.075260	0.001981		
Total	39	0.086150			

Table 0.119: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000090	0.000090	0.05	0.823
Residual	38	0.067660	0.001781		
Total	39	0.067750			

Table 0.120: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000250	0.000250	0.08	0.782
Residual	38	0.122540	0.003225		
Total	39	0.122790			

Table 0.121: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001210	0.001210		0.309
Residual	38	0.043180	0.001136		
Total	39	0.044390			

Table 0.122: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0036100	0.0036100	4.09	0.050
Residual	38	0.0335800	0.0008837		
Total	39	0.0371900			

Table 0.123: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0012100	0.0012100	1.41	0.242
Residual	38	0.0325400	0.0008563		
Total	39	0.0337500			

Table 0.124: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.70	2.70	0.18	0.678
Residual	38	586.18	15.43		
Total	39	588.88			

Table 0.125: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.156	0.156	0.05	0.822
Residual	38	116.101	3.055		
Total	39	116.258			

Table 0.126: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.00400	0.00400	0.04	0.841
Residual	38	3.72000	0.09789		
Total	39	3.72400			

Table 0.127: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.08100	0.08100	1.02	0.318
Residual	38	3.01000	0.07921		
Total	39	3.09100			

Table 0.128: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.04225	0.05224	0.60	0.444
Residual	38	2.68550	0.07067		
Total	39	2.72775			

Table 0.129: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.00625	0.00625	0.06	0.801
Residual	38	3.67350	0.09667		
Total	39	3.67975			

Table 130: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.4840	0.4840	3.27	0.078
Residual	38	5.6200	0.1479		
Total	39	6.1040			

Table 131: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0748	0.0748	0.27	0.606
Residual	38	10.5203	0.2769		
Total	39	10.5952			

Table 132: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	63.23	63.23	6.08	0.018
Residual	38	39495	10.39		
Total	39	458.18			

Table 133: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	40.553	40.553	6.51	0.015
Residual	38	236.683	6.229		
Total	39	277.237			

Table 134: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	14.295	14.295	1.95	0.171
Residual	38	278.418	7.327		
Total	39	292.713			

Table 135: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1162.48	1162.48	20.56	<0.001
Residual	38	2148.88	56.55		
Total	39	3311.36			

Table 136: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	16.65	16.65	0.29	0.592
Residual	38	2163.93	56.95		
Total	39	2180.57			

Appendix 4.3.2: Sensory analysis for harvest C

Number	Sex	Profession	Age	Testing Order			Degree of difference				Acceptability		Preferred
				1	2	3	slight	moderate	much	extreme	odd	duplicates	
1	M	IWE	60	O	**O**	C	X					X	
2	M	Phd in Postharvest	26	**C**	O	C	X					X	
3	M	Helpdesk	35	**C**	O	O		X			X		Conv
4	F	Cleaning staff	45	C	**C**	O		X				X	
5	F	Cleaning staff	26	C	**O**	C				X		X	Conv
6	F	IAT	43	**O**	C	C	X					X	Conv
7	F	IWE	58	O	**O**	C	X					X	
8	M	EO IT	38	C	**O**	C	X				X		Org
9	F	Canteen	36	**C**	O	O	X					X	Org
10	F	Canteen	50	C	**C**	O				X		X	
11	F	Lecturer in Postharvest	36	C	**O**	C	X					X	Conv
12	F	IWE	43	**O**	C	O	X					X	
13	F		57	O	O	**C**		X				X	Org
14	F	Library	41	C	O	**C**	X					X	
15	M	IWE	32	C	O	**O**	X					X	
16	M	PHD in postharvest	24	C	C	O							
17	M	Lecturer in postharvest	46	O	**C**	O	X					X	Org
18	M	Helpdesk	28	O	C	**C**	X					X	
19	F	Phd in Postharvest	26	O	O	**C**	X					X	Org
20	F	Phd in IBST	24	C	O	**C**		X			X		
21	M	Lecturer in Postharvest	44	**C**	O	O	X					X	Org
22	M	PhD	23	C	C	**O**	X				X		Org
23	F	Library	42	O	C	O							
24	F	Library	45	**O**	C	C		X			X		Org
25	M	Student	25	O	O	**C**	X	X				X	Org
26	F	Secretary IAT	55	**C**	O	C	X				X		
27	M	IAT	41	**C**	O	O	X					X	Org
28	M	MSc by research	25	**C**	C	O			X			X	
29	M	Goods inwards	63	**O**	C	O	X					X	
30	M	Grounds department	63	O	C	C							

Summary

Men/Female	15 / 15	Average	40			Total	21	6	1	2		Distinctivity	14
												Preference	Conv 4, Org 10

Appendix 4.4: Anova tables and sensory analysis for harvest D

Appendix 4.4.1: Anova tables for harvest D

Table 0.130: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	42.148	42.148	15.78	<0.001
Residual	278	742.749	2.672		
Total	279	784.897			

Table 0.131: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.112	0.112	0.05	0.815
Residual	278	567.112	2.040		
Total	279	567.224			

Table 0.132: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.092	0.092	0.09	0.772
Residual	38	41.055	1.080		
Total	39	41.147			

Table 0.133: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.002	0.002	0.00	0.978
Residual	38	106.490	2.802		
Total	39	106.492			

Table 0.134: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.2045	0.2045	0.30	0.586
Residual	38	25.7293	0.6771		
Total	39	25.9338			

Table 0.135: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.004	0.004	0.00	0.956
Residual	38	50.329	1.324		
Total	39	50.333			

Table 0.136: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	39.09	39.09	3.81	0.058
Residual	38	389.64	10.25		
Total	39	428.72			

Table 0.137: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	3.080	3.080	0.43	0.518
Residual	38	275.020	7.237		

Total	39	278.100

Table 0.138: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	71.26	71.26	5.54	0.024
Residual	38	488.47	12.85		
Total	39	559.73			

Table 0.139: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1917.5	1917.5	17.60	<0.001
Residual	38	4140.7	109.0		
Total	39	6058.2			

Table 0.140: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	8.665	8.665	6.34	0.016
Residual	38	51.927	1.366		
Total	39	60.592			

Table 0.141: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	28.5584	25.5584	73.40	<0.001
Residual	38	14.7848	0.3891		
Total	39	43.3431			

Table 0.142: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	5.5103	5.5103	13.95	<0.001
Residual	38	15.0124	0.3951		
Total	39	20.5226			

Table 0.143: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	3765.	3765.	2.54	0.119
Residual	38	56273.	1481.		
Total	39	60039			

Table 0.144: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	11.494	11.494	8.42	0.006
Residual	38	51.879	1.365		
Total	39	63.373			

Table 0.145: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	21.041	21.041	6.43	0.015
Residual	38	124.269	3.270		
Total	39	145.310			

Table 0.146: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.01186	0.01186	0.32	0.576
Residual	38	1.41905	0.03734		
Total	39	1.43091			

Table 0.147: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.28918	0.28918	2.95	0.094
Residual	38	3.72297	0.09797		
Total	39	4.01216			

Table 0.148: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.221	2.221	1.57	0.218
Residual	38	53.762	1.415		
Total	39	55.983			

Table 0.149: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.13576	0.13576	5.69	0.022
Residual	38	0.90718	0.02387		
Total	39	1.04294			

Table 0.150: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.38443	0.38443	19.25	<0.001
Residual	38	0.75890	0.01997		
Total	39	1.14333			

Table 0.151: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.11183	0.11183	5.85	0.020
Residual	38	0.72647	0.01912		
Total	39	0.83829			

Table 0.152: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.738	2.738	0.95	0.335
Residual	38	109.190	2.873	1.19	
Ban.Type.meth st.					
Method	1	963.272	963.272	399.83	<0.001
Type.Method	1	3.698	3.698	1.53	0.223
Residual	38	91.550	2.409		
Total	79	1170.448			

Table 0.153: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	46.8180	46.8180	17.76	<0.001
Residual	38	100.1740	2.6362	5.39	
Ban.Type.meth st.					
Method	1	323.2080	323.2080	661.24	<0.001
Type.Method	1	6.4980	6.4980	13.29	<0.001
Residual	38	18.5740	0.4888		
Total	79	495.2720			

Table 0.154: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.6125	0.6125	0.63	0.433
Residual	38	37.0670	0.9754	2.27	
Ban.Type.meth st.					
Method	1	1794.005	1794.005	418.05	<0.001
Type.Method	1	0.3125	0.3125	0.73	0.399
Residual	38	16.3070	0.4291		
Total	79	233.6995			

Table 0.155: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	1.9220	1.9220	2.75	0.106
Residual	38	26.5960	0.6999	1.02	
Ban.Type.meth st.					
Method	1	136.2420	136.2420	198.24	<0.001
Type.Method	1	0.2420	0.2420	0.35	0.556
Residual	38	26.1160	0.6873		
Total	79	191.1180			

Table 0.156: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.1125	2.1125	2.51	0.121
Residual	38	31.9430	08406	3.49	
Ban.Type.meth st.					
Method	1	235.9845	235.9845	980.80	<0.001
Type.Method	1	0.0125	0.0125	0.05	0.821
Residual	38	9.1430	0.2406		
Total	79	279.1955			

Table 0.157: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.8820	0.8820	0.52	0.476

Residual	38	64.5960	1.6999	4.01	
Ban.Type.meth st.					
Method	1	155.6820	155.6820	367.08	<0.001
Type.Method	1	0.8820	0.8820	2.08	0.157
Residual	38	16.1160	0.4241		
Total	79	238.1580			

Table 0.158: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.4805	0.4805	0.47	0.497
Residual	38	38.8350	1.0220	1.56	
Ban.Type.meth st.					
Method	1	202.8845	202.8845	309.44	<0.001
Type.Method	1	0.1805	0.1805	0.28	0.603
Residual	38	24.9150	0.6557		
Total	79	267.2955			

Table 0.159: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.006250	0.006250	4.74	0.036
Residual	38	0.050140	0.001319		
Total	39	0.056390			

Table 0.160: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.029702	0.029702	11.96	0.001
Residual	38	0.094395	0.002484		
Total	39	0.124098			

Table 0.161: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001000	0.001000	0.92	0.344
Residual	38	0.041360	0.001088		
Total	39	0.042360			

Table 0.162: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0016900	0.0016900	3.73	0.061
Residual	38	0.0172200	0.0004532		
Total	39	0.0189100			

Table 0.163: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0012100	0.0012100	3.31	0.077
Residual	38	0.0139000	0.0003658		
Total	39	0.0151100			

Table 0.164: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0015625	0.0015625	1.97	0.168

Residual	38	0.0300750	0.0007914		
Total	39	0.0316375			

Table 0.165: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0014400	0.0014400	3.13	0.085
Residual	38	0.0174700	0.0004597		
Total	39	0.0189100			

Table 0.166: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	14.40	14.40	0.82	0.370
Residual	38	664.66	17.49		
Total	39	679.06			

Table 0.167: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.002	0.002	0.00	0.979
Residual	38	116.495	3.066		
Total	39	116.498			

Table 0.168: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.1103	0.1103	0.96	0.334
Residual	38	4.3775	0.1152		
Total	39	4.4878			

Table 0.169: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.03025	0.03025	0.50	0.484
Residual	38	2.30350	0.06062		
Total	39	2.33375			

Table 0.170: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.04225	0.04225	0.55	0.463
Residual	38	2.91750	0.07678		
Total	39	2.95975			

Table 0.171: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.5290	0.5290	4.63	0.038
Residual	38	4.3420	0.1143		
Total	39	4.8710			

Table 0.172: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.9803	1.9803	15.95	<0.001
Residual	38	4.7175	0.1241		
Total	39	6.6978			

Table 0.173: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0473	0.0473	0.12	0.735
Residual	38	15.4226	0.4059		
Total	39	15.4698			

Table 0.174: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.42	2.42	0.15	0.705
Residual	38	631.69	16.62		
Total	39	634.11			

Table 0.175: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	45.945	45.945	5.38	0.026
Residual	38	324.383	8.536		
Total	39	370.328			

Table 0.176: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	29.54	29.54	0.93	0.341
Residual	38	12.06	31.74		
Total	39	1235.61			

Table 0.177: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	22.86	22.86	0.34	0.566
Residual	38	2591.99	68.21		
Total	39	2614.85			

Table 0.178: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	49.39	49.39	1.43	0.239
Residual	38	1313.02	34.55		
Total	39	1362.41			

Appendix 4.4.2: Sensory analysis for harvest D

Number	Sex	Profession	Age	Testing Order			degree of difference				acceptability		preferred
				1	2	3	slight	moderate	much	extreme	odd	duplicates	
1	M	MSc in GIS	22	o	**C**	o		X			X		Conv
2	F	Canteen	36	**c**	O	c		X			X		Org
3	M	Helpdesk	35	**O**	o	c		X			X		
4	F	IAT	43	c	**c**	O	X					X	Conv
5	F		58	O	**c**	c		X			X		Org
6	M	lecturer in postharvest	44	**C**	o	o		X			X		Conv
7	F		57	o	**C**	o	X				X		Conv
8	M	Goods inwards	63	c	**o**	c	X					X	
9	M	Student	24	**o**	o	C	X					X	Org
10	M	Phd in Postharvest	26	c	**c**	O		X			X		Org
11	M	PHD in postharvest	24	O	**c**	c	X				X		Org
12	F	Canteen	50	**c**	O	o		X				X	
13	M	PhD	23	o	C	**o**		X				X	Org
14	F	Library	42	C	o	**c**	X				X		
15	F	Library	45	O	o	**c**	X					X	
16	F	Library	50	c	C	o	X				X		
17	M	Student	25	O	**c**	c	X				X		Org
18	M	EO IT	38	c	O	o		X				X	
19	F	PHD in IBST	24	o	C	**o**		X				X	Org
20	M	Helpdesk	28	c	O	**c**	X					X	Conv
21	M	Lecturer in Postharvest	46	**o**	o	C		X			X		Conv
22	M	Grounds department	42	c	C	**o**	X					X	
23	M	technician IWE	43	O	c	c	X				X		Org
24	F	Reception	53	**c**	o	O		X			X		
25	M	Student IWE	34	o	C	**o**		X				X	Org
26	F	technician IAT	51	**c**	O	c	X					X	Conv
27	F	MSc in Envt	24	**o**	o	C						X	Conv
28	F	MSc in IWE	25	**c**	c	O					X		
29	F	PhD	29	**o**	C	c						X	
30	F	Student	32	c	O	o					X		

Summary

Men/Female 15 / 15 Average 38 Total 13 13 Distinctivity 18

Preference Conv 8, Org 10

Appendix 4.5: Anova tables and sensory analysis for harvest E
Appendix 4.5.1: Anova tables for harvest E

Table 0.173: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	8.175	8.175	4.03	0.046
Residual	278	567.473	2.030		
Total	279	572.648			

Table 0.174: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.236	0.236	0.19	0.663
Residual	278	345.555	1.243		
Total	279	345.791			

Table 0.175: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	9.370	9.370	3.76	0.060
Residual	38	94.645	2.491		
Total	39	104.015			

Table 0.176: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	35.382	35.382	9.69	0.004
Residual	38	138.804	3.653		
Total	39	174.804			

Table 0.177: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	7.9834	7.9834	12.80	<0.001
Residual	38	23.7060	0.6238		
Total	39	31.6894			

Table 0.178: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	13.179	13.179	3.83	0.058
Residual	38	130.709	3.440		
Total	39	143.888			

Table 0.179: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	104.30	140.30	9.33	0.004
Residual	38	424.71	11.18		
Total	39	529.00			

Table 0.180: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	8.24	8.24	0.76	0.389
Residual	38	411.79	10.84		
Total	39	422.03			

Table 0.181: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	104.17	104.17	9.32	0.004
Residual	38	424.64	11.17		
Total	39	528.81			

Table 0.182: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.1559	2.1559	3.73	0.061
Residual	38	21.9844	0.5785		
Total	39	24.1403			

Table 0.183: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	25.771	25.771	19.31	<0.001
Residual	38	50.714	1.335		
Total	39	76.485			

Table 0.184: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	19.1454	19.1454	32.98	<0.001
Residual	38	22.0620	0.5806		
Total	39	41.2075			

Table 0.185: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.7729	2.7729	4.33	0.044
Residual	38	24.3342	0.6404		
Total	39	27.1071			

Table 0.186: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	17.735	17.735	10.71	0.002
Residual	38	62.909	1.655		
Total	39	80.643			

Table 0.187: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.041	0.041	0.01	0.904
Residual	38	105.783	2.784		
Total	39	105.824			

Table 0.188: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	17.744	17.744	10.72	0.002
Residual	38	62.891	1.655		
Total	39	80.635			

Table 0.189: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.05265	0.05265	1.54	0.222
Residual	38	1.29789	0.03415		
Total	39	1.35054			

Table 0.190: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.248747	0.248747	30.66	<0.001
Residual	38	0.308250	0.008112		
Total	39	0.556996			

Table 0.191: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0963	0.0963	079	0.380
Residual	38	4.6309	0.1219		
Total	39	4.7272			

Table 0.192: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.49482	049482	15.89	<0.001
Residual	38	1.18354	0.03115		
Total	39	1.67835			

Table 0.193: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.33471	0.33471	31.79	<0.001
Residual	38	0.40005	0.01053		
Total	39	0.73476			

Table 0.194: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.49224	0.49224	26.44	<0.001
Residual	38	0.70740	0.01862		
Total	39	1.19963			

Table 0.195: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	10.224	10.224	4.17	0.048
Residual	38	93.103	2.450	1.17	
Ban.Type.meth st.					
Method	1	348.612	348.612	166.54	<0.001
Type.Method	1	9.384	9.384	4.48	0.041

Residual	38	79.543	2.093		
Total	79	540.868			

Table 0.196: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	15.4880	15.4880	9.16	0.004
Residual	38	64.2620	1.6911	3.42	
Ban.Type.meth st.					
Method	1	130.0500	130.0500	263.12	<0.001
Type.Method	1	0.9680	0.9680	1.96	0.170
Residual	38	18.7820	0.4943		
Total	79	229.5500			

Table 0.197: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.4500	2.4500	2.20	0.146
Residual	38	42.3000	1.1132	2.47	
Ban.Type.meth st.					
Method	1	101.2500	101.2500	225.00	<0.001
Type.Method	1	1.2500	1.2500	2.78	0.104
Residual	38	17.1000	0.4500		
Total	79	164.3500			

Table 0.198: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.4500	0.4500	0.42	0.522
Residual	38	40.8920	1.0761	1.36	
Ban.Type.meth st.					
Method	1	59.8580	59.8580	75.59	<0.001
Type.Method	1	0.4500	0.4500	0.57	0.456
Residual	38	30.0920	0.7919		
Total	79	131.7420			

Table 0.199: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.5445	0.5445	0.49	0.488
Residual	38	42.1910	1.1103	1.73	
Ban.Type.meth st.					
Method	1	10.2245	10.2245	15.90	<0.001
Type.Method	1	0.0045	0.0045	0.01	0.934
Residual	38	24.4310	06429		
Total	79	77.3955			

Table 0.200: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	2.8125	2.8125	2.58	0.117
Residual	38	41.4430	1.0906	2.22	
Ban.Type.meth st.					
Method	1	2.9645	2.9645	6.04	0.019
Type.Method	1	1.0125	1.0125	2.06	0.159
Residual	38	18.6430	0.4906		
Total	79	66.8755			

Table 0.201: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	5.9405	5.9405	4.50	0.041
Residual	38	50.2190	1.3216	2.88	
Ban.Type.meth st.					
Method	1	36.1805	36.1805	78.75	<0.001
Type.Method	1	1.7405	1.7405	3.79	0.059
Residual	38	17.4590	0.4594		
Total	79	111.5395			

Table 0.202: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0042025	0.0042025	6.67	0.014
Residual	38	0.0239350	0.0006299		
Total	39	0.0281375			

Table 0.203: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0011025	0.0011025	1.55	0.220
Residual	38	0.0269950	0.0007104		
Total	39	0.0280975			

Table 0.204: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001323	0.001323	1.25	0.271
Residual	38	0.040255	0.001059		
Total	39	0.041578			

Table 0.205: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0000025	0.0000025	0.00	0.949
Residual	38	0.0225350	0.0005930		
Total	39	0.0225375			

Table 0.206: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0000025	0.0000025	0.00	0.949
Residual	38	0.0225750	0.0005941		
Total	39	0.0225775			

Table 0.207: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0006400	0.0006400	1.30	0.261
Residual	38	0.0186700	00004913		
Total	39	0.0193100			

Table 0.208: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0016900	0.0016900	2.37	0.132
Residual	38	0.0270700	0.0007124		
Total	39	0.0287600			

Table 0.209: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	71.61	71.61	3.88	0.056
Residual	38	700.87	18.44		
Total	39	772.48			

Table 0.210: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	6.400	6.400	2.95	0.094
Residual	38	82.436	2.169		
Total	39	88.836			

Table 0.211: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.10000	0.10000	1.04	0.314
Residual	38	3.65500	0.09618		
Total	39	3.75500			

Table 0.212: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.19600	0.19600	3.94	0.054
Residual	38	1.88800	0.04968		
Total	39	2.08400			

Table 0.213: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.2250	1.2250	6.49	0.015
Residual	38	7.1710	0.1887		
Total	39	8.3960			

Table 0.214: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.7223	1.7223	16.44	<0.001
Residual	38	3.9815	0.1048		
Total	39	5.7037			

Table 0.215: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.9000	0.9000	5.19	0.028
Residual	38	6.5910	0.1734		
Total	39	7.4910			

Table 0.216: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.189	0.189	0.11	0.737
Residual	38	62.884	1.655		
Total	39	63.073			

Table 0.217: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.121	0.121	0.01	0.904
Residual	38	314.883	8.286		
Total	39	315.005			

Table 0.218: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.44	0.44	0.02	0.876
Residual	38	679.73	17.89		
Total	39	680.17			

Table 0.219: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	3.25	3.25	0.11	0.740
Residual	38	1105.46	29.09		
Total	39	1108.72			

Table 0.220: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	7.69	7.69	0.17	0.684
Residual	38	1741.92	45.84		
Total	39	1749.61			

Table 0.221: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0	0.0	0.00	0.988
Residual	38	4156.4	109.4		
Total	39	4156.5			

Appendix 4.5.2: Sensory analysis for harvest E

Number	Sex	Profession	Age	Testing Order			degree of difference				acceptability		preferred
				1	2	3	slight	moderate	much	extreme	odd	duplicates	
1	M	Phd in Postharvest	26	o	**C**	o	X				X		Conv
2	F	Cleaning staff	26	**c**	o	C		X				X	
3	M	Marketing	48	**o**	o	C			X			X	Org
4	F	Student	21	c	**C**	o		X				X	
5	M	Student	21	O	**c**	c		X			X		Org
6	F	IAT	43	**C**	o	o	X				X		Conv
7	F	IAT	58	o	**C**	o	X					X	Org
8	M	Helpdesk	35	c	**O**	c		X				X	Conv
9	F	Lecturer in Postharvest	36	**o**	O	c		X			X		
10	F	Phd in IBST	24	c	**C**	o		X			X		
11	M	EO IT	38	C	**o**	c		X				X	Conv
12	M	Goods inwards	55	**c**	O	o	X				X		
13	F	Library	42	o	C	**o**	X					X	Org
14	F	Library	50	C	o	**c**	X				X		
15	F	Library	45	o	o	**C**	X				X		Conv
16	F	Library	41	c	C	o	X					X	
17	M	Student	23	o	**C**	c	X				X		
18	M	Goods inwards	63	c	o	O	X				X		
19	M	Helpdesk	28	o	C	**o**		X			X		Conv
20	F	reception	53	c	O	**c**		X			X		Org
21	M	MSc by research	25	**o**	o	C			X		X		Conv
22	M	PHD in Postharvest	24	c	c	**O**	X						
23	F	PhD in IWE	26	O	c	c		X			X		Org
24	M	Lecturer in Postharvest	44	**c**	O	o		X				X	
25	F	Student	21	o	C	**o**		X				X	Org
26	F	MSc in Envt	24	**C**	o	c	X				X		
27	F	MSc in IWE	25	**O**	o	c		X			X		
28	M	Student	29	**c**	c	O		X				X	
29	M	Student	26	**o**	c	C	X					X	
30	M	Undergraduate	23	C	o	o		X			X		Conv

Summary

Men/Female	15 / 15	Average	35	Total	13	15	2	Distinctivity	15
								Preference	Conv 8, Org 7

Appendix 4.6: Anova tables and sensory analysis for harvest F
Appendix 4.6.1: Anova tables for harvest F

Table 0.216: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	108.278	108.278	48.94	<0.001
Residual	278	615.036	2.212		
Total	279	723.314			

Table 0.217: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	13.360	13.360	12.23	<0.001
Residual	278	303.611	1.092		
Total	279	316.972			

Table 0.218: Lightness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.001	0.001	0.00	0.990
Residual	38	322.838	8.496		
Total	39	322.839			

Table 0.219: Lightness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	4.809	4.809	1.13	0.294
Residual	38	161.145	4.241		
Total	39	165.954			

Table 0.220: Lightness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	31.135	31.135	9.06	0.005
Residual	38	130.588	3.437		
Total	39	161.723			

Table 0.221: Lightness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.202	0.202	0.08	0.775
Residual	38	92.565	2.436		
Total	39	92.767			

Table 0.222: Lightness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	12.645	12.645	1.44	0.238
Residual	38	334.197	8.795		
Total	39	346.842			

Table 0.223: Lightness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.02	1.02	0.07	0.788
Residual	38	530.91	13.97		
Total	39	531.93			

Table 0.224: Lightness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.04	0.04	0.00	0.977
Residual	38	1769.90	46.58		
Total	39	169.94			

Table 0.225: Hue angle day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	927.7	927.7	2.45	0.126
Residual	38	14405.9	379.1		
Total	39	15333.7			

Table 0.226: Hue angle day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	79.612	79.612	47.89	<0.001
Residual	38	63.168	1.662		
Total	39	142.780			

Table 0.227: Hue angle day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	57.183	57.183	50.46	<0.001
Residual	38	43.063	1.133		
Total	39	100.246			

Table 0.228: Hue angle day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.5038	0.5038	1.02	0.318
Residual	38	18.6880	0.4918		
Total	39	19.1918			

Table 0.229: Hue angle day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.171	1.171	0.39	0.535
Residual	38	113.275	2.981		
Total	39	114.446			

Table 0.230: Hue angle day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	8.161	8.161	1.28	0.265
Residual	38	241.797	6.363		
Total	39	249.958			

Table 0.231: Hue angle day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.039	0.039	0.01	0.936
Residual	38	228.146	6.004		
Total	39	228.185			

Table 0.232: Relative fresh weight, day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.044595	0.044595	7.48	0.009
Residual	38	0.226550	0.005962		
Total	39	.0271145			

Table 0.233: Relative fresh weight, day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.030033	0.030033	4.14	0.049
Residual	38	0.275833	0.007259		
Total	39	0.305866			

Table 0.234: Relative fresh weight, day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.004372	0.004372	0.57	0.455
Residual	38	0.291868	0.007681		
Total	39	0.296239			

Table 0.235: Relative fresh weight, day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.017232	0.017232	1.95	0.171
Residual	38	0.336236	0.008848		
Total	39	0.353468			

Table 0.236: Relative fresh weight, day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.00056	0.00056	0.04	0.842
Residual	38	0.52549	0.01383		
Total	39	0.52604			

Table 0.237: Relative fresh weight, day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.20070	0.20070	2.52	0.121
Residual	38	3.03090	0.07976		
Total	39	3.23160			

Table 0.238: TSS day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	11.101	11.101	3.89	0.056
Residual	38	108.439	2.854	1.58	
Ban.Type.meth st.					
Method	1	362.100	362.100	199.88	<0.001
Type.Method	1	12.961	12.961	7.15	0.011
Residual	38	68.839	1.812		
Total	79	563.440			

Table 0.239: TSS day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	1.8000	1.8000	1.39	0.246
Residual	38	49.2380	1.2957	1.89	
Ban.Type.meth st.					
Method	1	260.6420	260.6420	379.80	<0.001
Type.Method	1	0.0000	0.0000	0.00	1.00
Residual	38	26.0780	0.6863		
Total	79	337.7580			

Table 0.240: TSS day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.4000	0.4000	0.37	0.551
Residual	38	19.5400	1.0856	1.97	
Ban.Type.meth st.					
Method	1	36.1000	36.1000	65.37	<0.001
Type.Method	1	0.4000	0.4000	0.72	0.406
Residual	38	9.9400	0.5522		
Total	79	66.3800			

Table 0.241: TSS day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0405	0.0405	0.03	0.865
Residual	38	52.7350	1.3878	2.09	
Ban.Type.meth st.					
Method	1	99.9045	99.9045	150.32	<0.001
Type.Method	1	0.2205	0.2205	0.33	0.568
Residual	38	25.2550	0.6646		
Total	79	178.1555			

Table 0.242: TSS day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.6125	0.6125	0.63	0.433
Residual	38	37.0150	0.9741	1.41	
Ban.Type.meth st.					
Method	1	49.6125	49.6125	71.92	<0.001
Type.Method	1	0.3125	0.3125	0.45	0.505
Residual	38	26.2150	0.6899		
Total	79	113.7675			

Table 0.243: TSS day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.0720	0.0720	0.05	0824
Residual	38	54.8560	1.4436	2.64	
Ban.Type.meth st.					
Method	1	18.4320	18.4320	33.71	<0.001
Type.Method	1	0.0720	0.0720	0.13	0.719
Residual	38	20.7760	0.5467		

Total	79	94.2080

Table 0.244: TSS day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Banana stratum					
Type	1	0.2420	0.2420	0.34	0.562
Residual	38	26.8700	0.7071	2.13	
Ban.Type.meth st.					
Method	1	0.1280	0.1280	0.39	0.538
Type.Method	1	1.9220	1.9220	5.80	0.021
Residual	38	12.5900	0.3313		
Total	79	41.7520			

Table 0.245: Titratable acidity day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.008122	0.008122	4.07	0.051
Residual	38	0.075815	0.001995		
Total	39	0.083937			

Table 0.246: Titratable acidity day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000563	0.000563	0.46	0.504
Residual	38	0.046915	0.001235		
Total	39	0.047477			

Table 0.247: Titratable acidity day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.008000	0.008000	4.59	0.046
Residual	18	0.031400	0.001744		
Total	19	0.039400			

Table 0.248: Titratable acidity day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.097023	0.097023	26.03	<0.001
Residual	38	0.141655	0.003728		
Total	39	0.238678			

Table 0.249: Titratable acidity day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.000022	0.000022	0.01	0.923
Residual	38	0.090275	0.002376		
Total	39	0.090297			

Table 0.250: Titratable acidity day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0003025	0.0003025	0.40	0.530
Residual	38	0.0286750	0.0007546		
Total	39	0.0289775			

Table 0.251: Titratable acidity day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0000400	0.0000400	0.08	0.777
Residual	38	0.0187500	0.0004934		
Total	39	0.0187900			

Table 0.252: Firmness day 0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	17.69	17.69	0.86	0.360
Residual	38	783.21	20.61		
Total	39	800.90			

Table 0.253: Firmness day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	6.162	6.162	2.67	0.110
Residual	38	87.618	2.306		
Total	39	93.780			

Table 0.254: Firmness day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	1.2500	1.2500	12.15	0.003
Residual	18	1.8520	0.1029		
Total	19	3.1020			

Table 0.255: Firmness day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.15625	0.15625	1.79	0.189
Residual	38	3.32150	0.08741		
Total	39	3.47775			

Table 0.256: Firmness day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.50625	0.050625	8.34	0.006
Residual	38	2.30750	0.06072		
Total	39	2.81375			

Table 0.257: Firmness day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.78400	0.78400	8.53	0.006
Residual	38	3.49200	0.09189		
Total	39	4.27600			

Table 0.258: Firmness day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	0.0810	0.0810	0.27	0.605
Residual	38	11.3190	0.2979		
Total	39	11.4000			

Table 0.259: Starch content day 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.8114	2.8114	3.38	0.074
Residual	38	31.6212	0.8321		
Total	39	34.4326			

Table 0.260: Starch content day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	2.2	2.2	0.00	0.959
Residual	38	30717.8	808.4		
Total	39	30720.0			

Table 0.261: Starch content day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	7.809	7.809	1.06	0.310
Residual	38	279.781	7.363		
Total	39	287.590			

Table 0.262: Starch content day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	17.14	17.14	0.83	0.368
Residual	38	783.32	20.61		
Total	39	800.46			

Table 0.263: Starch content day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	274.27	274.27	2.83	0.100
Residual	38	3677.67	96.78		
Total	39	3951.94			

Table 0.264: Starch content day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Type	1	51.82	51.82	1.17	0.287
Residual	38	1688.41	44.43		
Total	39	1740.23			

Appendix 4.6.2 Sensory analysis for harvest F

Number	Sex	Profession	Age	Testing Order			degree of difference				acceptability		preferred
				1	2	3	slight	moderate	much	extreme	odd	duplicates	
1	M	Phd in Postharvest	26	c	**o**	C	X				X		
2	F	Student	21	**o**	C	o		X				X	Org
3	F	secretary postharvest	55	**o**	c	c							
4	M	Student	26	c	**O**	o	X					X	
5	F	Cleaning staff	26	c	**c**	O			X		X		
6	M	Helpdesk	35	**o**	o	C	X					X	Org
7	F	IAT	43	C	**o**	c	X					X	
8	M	Student	25	O	**c**	o	X					X	
9	F	IAT	58	**o**	c	c							
10	F	Phd in	23	c	**o**	o		X			X		
11	F		57	c	**c**	O		X			X		Org
12	M	PHD in Postharvest	24	**o**	o	C	X					X	Org
13	M	Student	23	C	o	**c**		X				X	
14	M	Marketing	48	O	c	**o**						X	
15	M	Goods inwards	63	o	c	**C**	X					X	
16	F	Student	21	c	O	o	X				X		
17	M	Student	32	c	**C**	o		X				X	
18	F	Library	42	o	O	c		X				X	
19	F	Secretary IAT	55	C	o	**c**	X					X	
20	M	IBST	46	o	C	**o**		X				X	Org
21	F	reception	53	**O**	c	c			X		X		Org
22	M	Student IWE	34	C	o	**o**		X			X		Conv
23	M	Student	26	c	c	O			X			X	Conv
24	F	Phd in IBST	24	**o**	O	c	X				X		
25	M	EO IT	38	c	O	**c**	X				X		Org
26	F	Canteen	50	**o**	c	O	X					X	
27	M	IBST	37	**o**	c	C	X					X	
28	M	Helpdesk	28	**C**	o	o			X			X	Org
29	F	Canteen	36	**c**	c	O	X				X		Org
30	M	Lecturer in Postharvest	46	o	o	C	X					X	Org

Summary

Men/Female 16 / 14 Average 37 Total 15 8 4 Distinctivity 12

Preference Conv 2, Org 10

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